General Motors Upfitter Integration

2018

BEST PRACTICES GUIDELINE MANUAL

- INTRODUCTION
- BODY
- CHASSIS
- ELECTRICAL
- PAINT & SEALING

Index

A. Objectives 1

B. Important: A Word About This Guide 1

C. Defining the Guideline Manual 1

D. Upfitter Integration Expectations 2

E. Continuous Improvement 2

F. Key Product Characteristics 2

G. Reference Materials 3

H. Vehicle Weight 3

I. Serviceability 4

J. Torque Specifications 4

K. Special Vehicle Manufacturer's Body 4

L. Body Sealing 5

M. SVM Responsibility 5

N. Responsibility for Complete Vehicle Document 5

O. Incomplete Vehicle Document 6

P. Characteristics of a Compliance Control System 6

Q. Noise Emission Standards for Transportation Equipment:
Medium and Heavy Trucks – 40 CFR Part 205 7

R. Federal Regulations – Tires 8

S. Personnel and Process Controls 8

T. General Information 9

Introduction

A. Objectives

The objective of the UPFITTER INTEGRATION GROUP is to provide assistance to the Special Vehicle Manufacturer (SVM) to assure that converted, upfitted and modified vehicle quality, reliability and durability meet or exceed the expectations of our mutual customers resulting in total customer satisfaction.

B. Important: A Word About This Guide

This guide is intended for use by RV truck and commercial upfitters with expertise in their field. It, and periodically other support, is offered to assist RV and commercial truck upfitters in converting/completing RV and Commercial Truck vehicles; however, it is not intended to be a complete “how-to” authority, or a substitute for sound engineering and other judgment. The conversion and modification of vehicles requires skills and knowledge not covered in this guide. Neither General Motors, nor their representatives, assume any responsibility for the RV and commercial truck upfitters’ work, including their design, materials, and workmanship.

Please direct technical questions or problems not covered in this manual to the Upfitters Integration Group Hotline **(800) 875-4742**.

C. Defining The Guideline Manual

This Upfitter Integration Best Practices Guideline Manual provides engineering recommendations and guidelines to assist the Special Vehicle Manufacturer (SVM) for all areas of the vehicle affected in the conversion process. The intent is to assure that the finished vehicle meets or exceeds Original Equipment Manufacturer (OEM) quality.

The primary focus of the Guideline Manual is the G Van, and C/K Truck. However, most recommendations are generic and can be applied to all GM models that are modified.

The recommendations and guidelines in this manual are based on documented engineering principles and a philosophy of continuous improvement. However, they also take into consideration the other factors that SVMs face, such as, cost, timing, and resource pressure.

The Upfitter Integration group recommends that all SVMs become familiar with this manual and the reference publications listed herein before starting the process. These guidelines stress vehicle safety, quality, reliability and durability. However, each SVM also has the responsibility to:

- Make sure that vehicle modifications do not reduce the vehicle’s integrity.
- Comply with all Federal, State and local regulations.
- Verify that vehicle safety is maintained.
- Meet or exceed the requirements and expectations of the customer.

To simplify the appearance of this manual and make it easier to use, special symbols were created to draw your attention to important information:

!	Please take special note of this information.
CAUTION	Failure to comply may cause damage to the vehicle.
WARNING	Failure to comply may result in human injury.
⊘	This procedure is not recommended.

Introduction (cont'd)

General Motors Corporation requires confidentiality in the exchange of information with Special Vehicle Manufacturers. General Motors will honor all requests for confidentiality from the SVMs and expects, in return, that all General Motors product information will be treated as confidential material.

D. Upfitter Integration Expectations

The success of the Upfitter Integration group depends on an atmosphere of communication, cooperation and trust between SVMs and General Motors. Therefore, SVMs are expected to use the Upfitter Integration resources available to them (i.e., telephone hotline, quality surveys, guideline manuals and Upfitter Integration engineering expertise). SVMs are expected to have documented processes which are understood and accepted by all. Documented processes should be in place at work stations, followed explicitly and monitored for effectiveness.

E. Continuous Improvement

! The Upfitter Integration group expects all SVMs to establish a company-wide continuous improvement process to focus on achieving and maintaining total customer satisfaction.

A continuous improvement plan should describe the processes SVMs use to implement continuous improvement and the methods used to monitor and evaluate the effectiveness of all processes.

Continuous improvement is an ongoing customer-driven process. It enables all personnel in an organization to contribute to achieving the primary business goals of optimizing quality, cost, and delivery while eliminating organizational waste

F. Key Product Characteristics

Key product characteristics are the features of a vehicle or system that have the greatest impact on total customer satisfaction. Significant variation in these areas could adversely affect safety, quality, vehicle performance, etc. Typically, key product characteristics can be seen, touched, and felt by customers.

! It is the SVM’s responsibility to identify all pertinent key product characteristics.

General Motors encourages all SVMs to use documented processes for guaranteeing that all key product characteristics are maintained on a consistent basis. The process should identify measurable specifications for acceptance/rejection to maintain in-process quality control.

Therefore, the SVM should develop processes that both identify and control key product characteristics and also assure vehicle safety, quality, reliability, and durability.

Introduction (cont'd)

G. Reference Materials

Throughout this manual you will see references to the following publications:

- Federal Motor Vehicle Safety Standards (FMVSS) and Canada Motor Vehicle Standards (CMVSS)
- Society of Automotive Engineers (SAE) recommended procedures
- General Motors Service Manuals
- General Motors Truck Body Builders Manual
- General Motors Incomplete Vehicle Document
- Industrial Fasteners Institute Standards (Metric and English)
- RVIA Handbook
- NTEA Publications
- Delphi Packard Electric Connection Systems Catalog
- Delphi Packard Electric Manuals
  - — Product Engineering Handbook
  - — Wire Routing Design Quality Guidelines

H. Vehicle Weight

General Motors vehicles are designed to perform effectively within specific total weight and weight distribution ranges. The SVMs must not add weight to the vehicle which would cause the vehicle to exceed GVWR or GAWR.

- GVWR — Gross Vehicle Weight Rating is the total weight of a loaded truck. GVW is found by adding the payload weight to the curb weight of a vehicle. GVWR is the maximum allowable GVW for an individual chassis and body type.
- GAWR — Gross Axle Weight Rating is the maximum allowable GAW for either the front or rear axle.

! Modifications resulting in weights which exceed the GVWR or GAWR are not approved by General Motors and may violate federal certification. If this condition occurs, the SVMs will be required to recertify compliance to all applicable federal regulations. An overweight condition would also have an adverse effect on over-all vehicle performance and customer satisfaction.

WARNING Significant variations in vehicle weight and/or distribution could affect the following areas:

Performance to FMVSS/CMVSS requirements

- Occupant safety
- Center of gravity location
- Brake performance
- Front and rear axle loads
- Front and rear spring loads
- Tire loads
- Vehicle handling and steering

One acceptable way to verify compliance to vehicle weight specifications is to weigh each vehicle model before it leaves the SVM's facility.

For more detailed information about weight, refer to the General Motors Truck Body Builders Manual.

Introduction (cont'd)

I. Serviceability

Serviceability is important to total customer satisfaction.

Ease of serviceability is most important in areas that require regularly scheduled maintenance and will reduce overall warranty expense.

The SVMs can contribute to ease of serviceability in the following ways:

- Pay special attention to regular maintenance items.
- Make sure that maintenance can be performed with common shop tools.
- Keep critical adjustments to a minimum.
- Provide adequate tool access.
- Provide a simple method to determine cause of failure with a minimum of test equipment.
- Specify reusable fasteners where possible.
- Use components that can be rebuilt to original design specifications.
- Provide aligning holes, dimples, or cutouts on mating flanges for ease of reassembly.
- Include all relevant service documentation in the vehicle's Owners Manual.

J. Torque Specifications

CAUTION It is the SVM's responsibility to identify all critical fasteners and torque specifications. Assemblers should have proper tools and equipment to assure that torque specifications are met. A schedule for tool torque calibration is recommended.

Critical fasteners are defined as those fasteners where loss of function would affect (but not be limited to) the following areas:

- All regulatory conformance (Federal, State, local)
- Occupant safety
- Loss of vehicle control

The SVMs should use a documented quality control process to monitor vehicle assembly. Assembly tools and equipment must be maintained to calibrated specifications. For more information, refer to Appendix II in the Body section of this manual (General Fastener) and the Industrial Fasteners Institute Standards.

K. Special Vehicle Manufacturer's Body

- Assure that all required labels that warn, instruct or inform are located on the vehicle where they can be read easily or as required by government regulation.
- Provide the customer with a method of direct contact such as a toll free line.
- Use a customer survey process to measure customer satisfaction.
- Consult legal counsel and FMVSS/CMVSS to determine SVMs' responsibilities with respect to labeling.

Introduction (cont'd)

L. Body Sealing

All holes or cutouts in the body must be thoroughly sealed. Self-sealing fasteners, pumpable sealers or any other approved sealing system should be used to assure that there is no water or carbon monoxide intrusion into the vehicle. See the Upfitter Integration Paint and Sealing Guideline Manual.

M. SVM Responsibility

Compliance or implementation of recommendations in this manual are not to be construed as a substitute for verifying compliance to any federal, state or local regulations. Compliance to all standards remains the responsibility of the SVM as the final stage manufacturer.

General Motors does not take responsibility for the quality of components, methods, materials or workmanship of the SVMs, or against incidents that may result from the conversion of General Motors vehicles.

The federal government has established motor vehicle safety standards for various categories of motor vehicles and motor vehicle equipment under the provision of the National Traffic and Motor Vehicle Safety Act of 1966. The Act identifies important legal responsibilities of manufacturers, dealers, body builders, and others engaged in the manufacturing and marketing of motor vehicles and motor vehicle equipment.

Questions dealing with the specific application of the Act or the Standards to your own business should be discussed with your legal counsel. This is especially important because standards and other requirements/interpretations are subject to change by the government agency in charge: the National Highway Traffic Safety Administration (NHTSA).

New standards and amendments issued by the National Highway Traffic Safety Administration will appear in the Federal Register from time to time. You may obtain the Federal Register through the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

It is also the responsibility of the SVM to:

- Assure that all required labels that warn, instruct or inform are located on the vehicle where they can be easily read. Consult legal counsel and the FMVSS/CMVSS to determine SVM responsibility with respect to labeling.
- Provide the customer with a method of direct contact such as a toll free line.
- Use a customer survey process to measure customer satisfaction.
- Maintain a clean and well-organized manufacturing facility.
- Road test vehicles to expose discrepancies in the design and build processes.

N. Responsibility For Complete Vehicle Performance

General Motors performs extensive testing on all vehicles described in this manual. Major changes to a complete vehicle or the installation of a body by an upfitter on an incomplete vehicle chassis will affect vehicle performance.

It is the responsibility of the Special Vehicle Manufacturer to validate final completed vehicle performance. Total vehicle system performance tests may be required. The test schedule must reflect the type of vehicle system conditions to which the completed vehicle will be subjected to and must also include consideration of all aspects of performance, such as durability, ride and handling.

Introduction (cont'd)

O. Incomplete Vehicle Document

An Incomplete Vehicle Document is supplied with each incomplete vehicle. It provides instructions for intermediate and final stage manufacturers to use in determining conformity to applicable Federal Motor Vehicle Safety Standards (FMVSS). This document also includes instructions which must be followed to assure that EPA and California emission certification requirements are met.

In addition, General Motors provides a GM Body Builders Manual for the Special Vehicle Manufacturer to use in the completion of the vehicle. In no case should any SVM alterations affect the function, physical or mechanical properties, environment or vital space clearance of the components, assemblies, or systems of the incomplete vehicle.

! The Incomplete Vehicle Document also specifies that the center of gravity location be within certain limits for proper brake balance, and may be more restrictive than the data mentioned above. The SVM must use all appropriate data.

For further assistance, contact General Motors by calling the Upfitter Integration Hotline at **1-800-875-4742** or visit the upfitter web site: **www.gmupfitter.com**.

P. Characteristics Of A Compliance Control System

! The following recommendations are suggested as guidelines for developing a compliance control system:

- Assign a designated person to be responsible for the interpretation and compliance to FMVSS, CMVSS and other government regulations.
- Use a documented process to assure compliance with FMVSS and CMVSS regulations. Include a formal analysis in writing with appropriate document signoff.
- Keep on file in the Engineering Department a formal engineering change control system, which documents product and process changes.

! Perform a design and process PFMEA (Potential Failure Mode Effects and Analysis) on any design modifications made to the OEM cab/chassis to assure reliability and build consistent with all OEM specifications and guidelines.

WARNING Perform a weight and balance analysis on each model vehicle to assure compliance to OEM specifications. Never exceed OEM GVWR or GAWR specifications. Refer to the “Incomplete Vehicle Document” section for additional data. The significant elements for weight and balance analysis are:

— OEM base vehicle

— SVM conversion (including all permanently attached equipment)

— All fluids (at full levels) required to operate the vehicle

— Occupant (driver and all other belted positions weights

— Maximum cargo capacity

- Provide manufacturing and assembly personnel with engineering drawings and assembly procedures.

Introduction (cont'd)

P. Characteristics Of A Compliance Control System *(continued)*

- Use a final inspection process and include the documented results with the vehicle records. The results should have clear accept/reject criteria, and should include the following systems:
  - — Engine cooling
  - — Engine and transmission performance, including downshift and PRNDL indexing
  - — High idle RPM setting and full throttle pedal travel
  - — Fuel system leaks
  - — Exhaust shielding and leaks
  - — Body/cab leaks
  - — Electrical performance
  - — Brake performance
  - — Parking brake performance
  - — Ride/handling/steering
  - — Vehicle vibrations and noise
  - — Heater/air conditioning function and leak test
  - — A/C recharge capacity labels
  - — Paint code

Q. Noise Emission Standards For Transportation Equipment: Medium and Heavy Trucks – 40CFR Part 205

The U.S. Environmental Protection Agency (EPA) has established noise emission standards applicable to vehicles manufactured after January 1, 1978, under the provisions of the Noise Control Act of 1972 (in general, vehicles in excess of 10,000 pounds GVWR capable of transportation of property on a street or highway). The standard provides that vehicles manufactured after January 1, 1988, must conform to a maximum 80 dBA level.

The Act and the standards impose legal obligations on vehicle manufacturers and subsequent manufacturers. Questions about the standard’s definition of a “vehicle” or the specific application of the Act or its standards to your own business should be discussed with your legal counsel. This is especially important because of the EPA’s broad definition of a “vehicle”.

Standards or interpretations of such standards are subject to change by the EPA. New standards or amendments issued by the Environmental Protection Agency appear in the Federal Register from time to time. You may obtain the Federal Register through the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Introduction (cont'd)

R. Federal Regulations – Tires

The National Highway Traffic Safety Administration has issued regulations dealing with tire identification and record keeping which became effective May 22, 1971. Under these regulations important legal responsibilities are imposed upon tire manufacturers, brand name owners, retreaders, distributors and dealers, and motor vehicle manufacturers and dealers, to maintain and/or report certain information concerning tires. This information will be used to facilitate interest of safety. If you have any questions concerning the application of these regulations to your business, we suggest you consult with your legal counsel.

In order for General Motors to meet its responsibility under these tire regulations we have a record of the tires on each vehicle we shipped to you. If you do not change a tire on a General Motors vehicle, it is important that you make sure that it is reshipped with the same tires that were on it when the vehicle was received by you. This means that any tire which you remove from a vehicle during the course of your work should be put back on the same vehicle.

If you replace a tire on a General Motors vehicle, you are responsible for maintaining records of the vehicle identification number (VIN) and the vehicle owner to allow notification, through your records, if tire problems are found.

In case you should receive a defect notification from a tire manufacturer concerning tires which you installed on a vehicle returned to us, you may forward it to us so that we can send it to the vehicle owner whose name will appear on our records.

S. Personnel And Process Controls

The General Motors vehicle systems are highly complex in their operation and componentry, and extremely sensitive to SVM alterations and/or additions. Therefore, to assure vehicle system quality in every vehicle, a climate of constant and careful attention to processing details must be established. Doing so will aid in the production of problem free vehicles, the promotion of customer satisfaction and reduction of warranty expense.

General Motors recommends that all personnel involved in the design, installation and testing of the vehicle systems thoroughly understand the information contained in this manual. Additionally, it is suggested that the SVM adopt the practices and procedures described in this manual and appoint a qualified individual to coordinate all activities related to the processing of the vehicle systems.

Ideally, the SVM’s vehicle coordinator would have a combination of technical, communication and administrative skills that would enable him/her to perform several important functions. These functions would include implementing, monitoring and controlling all vehicle processes including assembly, installation, repair, maintenance, quality control and evaluation; identifying problems and recommending solutions; coordinating activities between departments and groups; gathering, interpreting and disseminating necessary technical and administrative data and other information.

Introduction (cont'd)

T. General Information

! In the event the reader should conclude that the General Motors recommendations in this manual conflict with the ANSI/RVIA standards or with any recommendations and/or directions furnished with any components that the SVM installs, the SVM should contact the General Motors Upfitter Integration group for clarification and/or guidance. (**1-800-875-4742**).

No recommendations in this manual knowingly conflict with any FMVSS, CMVSS, state and/or local regulations. In the event it is deemed there may be a conflict, the federal, state and/or local regulations shall take precedence.

The guidelines and information in this manual are not intended to supplant any standards, instructions, requirements, directions, etc., that are included in the following General Motors documents and/or manuals:

- Incomplete Vehicle Document
- GM Body Builders Manual(s)
- Service Manual(s)
- Driveability, Emissions and Electrical Diagnosis Manual(s)

In the event the reader should conclude that there is a conflict, the information contained in the above documents shall take precedence.

WARNING It is the SVM’s responsibility to maintain the structural integrity of the OEM vehicle body. To assure this, SVMs should conduct appropriate testing and engineering analyses when modifying any structure of the vehicle’s body.

Index

BODY STRUCTURE **1**
- Window Cutouts 1
- Side Wall Structure 2
- Roof Structure 2
- Floorpan 3

WEATHERSTRIPPING **4**
- Weatherstrip Installation 4
- Weatherstrip Inspection Process 5

BODY EXTERIOR COMPONENTS **5**
- Ladders, Spare Tire Carriers and Luggage Racks 5
- Lower Body Treatments 6
- Running Boards 6

BODY INTERIOR COMPONENTS **7**
- Headliner System 7
- Sun Visors 7
- Floor Covering 8
  - Carpeting 8
  - Sound Absorber and Deadener 8
- Interior Trim Panels 8
  - Plastic Trim Components 8
  - Wood Trim Components 8

RESTRAINTS AND SEAT ASSEMBLIES **9**
- Installation/Torque Specifications 9

Index

FASTENERS **10**
Metal Fasteners 10
Plastic Fasteners 11
Squeaks and Rattles.......... 11

APPENDIX I **12**
Welding Guidelines and Precautions.......... 12
Welding Precautions 12
Electrical System 13

APPENDIX II.......... **14**
General Fastener – Reference.......... 14
Fastening to Thin Sheet Metal 14
Fastener Details.......... 15

APPENDIX III.......... **23**
Design Principles to Eliminate Squeak & Rattle – General Principles 23
'KISS" Principles.......... 23
Instrument Panel 24
Electrical.......... 26
Interior Trim.......... 28
Body & Exterior Trim.......... 29
Seats.......... 30
Seat Belts 32

Body – Structure

Window Cutouts

When installing additional windows during the conversion process, it is important to implement practices that will not compromise the quality of the OEM vehicle. Additionally, standard procedures help to obtain consistent results. General Motors recommends the following:

! Use templates and fixtures when locating side windows. Use pre-existing features, such as the drip rail or body opening line, as reference points to locate templates and fixtures. (See Figures 1 and 2.)

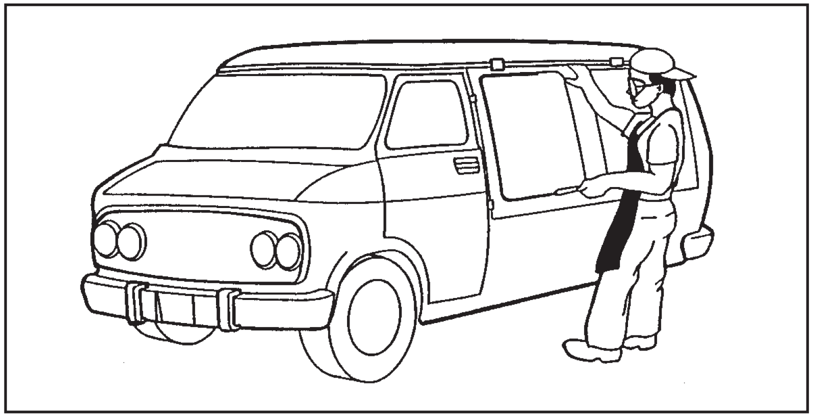


Figure 1

- When preparing raw metal edges, eliminate all sharp edges so metal preservative will adhere properly (Figure 3). Apply rust inhibitor around all body cutouts and holes drilled through exterior painted body panels. See the Upfitter Integration Paint and Sealing Guideline Manual.

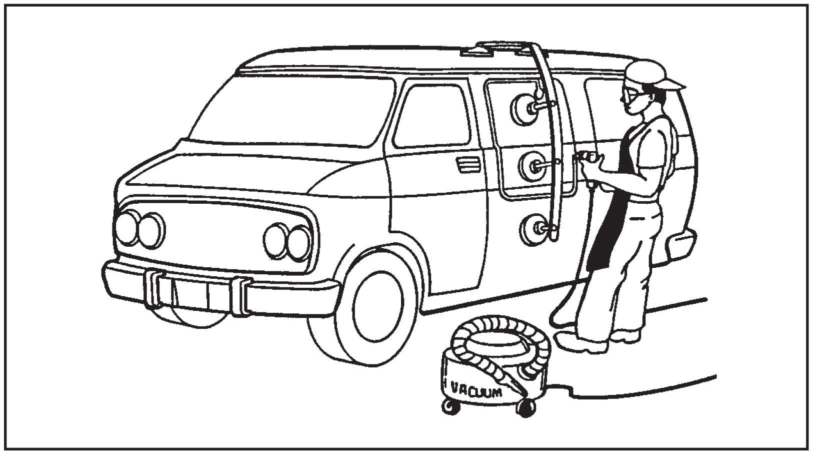


Figure 2

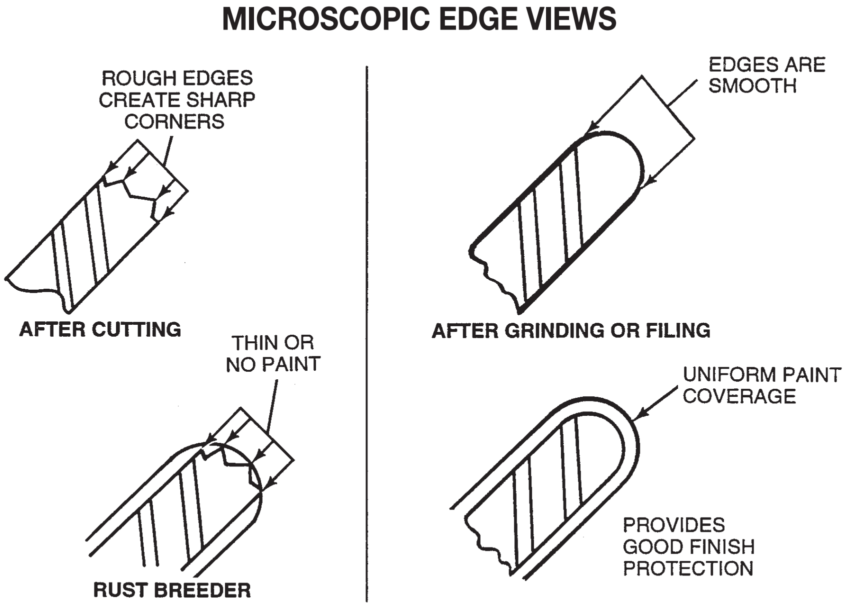

MICROSCOPIC EDGE VIEWS
ROUGH EDGES CREATE SHARP CORNERS
AFTER CUTTING
EDGES ARE SMOOTH
AFTER GRINDING OR FILING
THIN OR NO PAINT
RUST BREEDER
UNIFORM PAINT COVERAGE
PROVIDES GOOD FINISH PROTECTION

Figure 3

Body – Structure (cont'd)

- With a high-powered vacuum remove all metal debris| (i.e., chips, ribbons, slivers, etc.) from the interior of the vehicle. This process eliminates potential damage to electrical wires and moving parts. It also helps to prevent premature rusting of the vehicle body.
- When adding exterior components, choose only those made of non-corrosive or properly plated materials.

! Also, consider the corrosive effect of mating dissimilar metals when selecting materials. (See Paint manual for specific metal corrosion recommendations.)

CAUTION Conduct water testing to check for any leaks between the newly installed windows and the body, which may occur from the conversion process.

! Consult the Incomplete Vehicle Document for recommended locations for installing side body windows.

All SVM-installed window and sunroof glass must meet FVMSS and appropriate state regulations, including those governing the use of shaded glass. Certification markings for any upfitter-installed glass must be visible on the vehicle. The SVM is responsible for recertifying the vehicle when installing non-OEM glass.

Side Wall Structure

It is necessary to assure that the strength of the modified sidewall structure is equal to or greater than that supplied with the OEM vehicle.

WARNING Install additional structures by bolting or welding them to the basic members of the body structure such as the roof rail, floor pan, wheel house, pillars or horizontal and vertical strainers.

CAUTION Refer to the Appendix I for general welding guidelines.

CAUTION For electrical system welding precautions, see the Upfitter Integration Electrical Guideline Manual — Electrical System Precautions section.

Roof Structure

CAUTION General Motors recommends the following guidelines for modifying G-Van and M/L Van roof structures (see the incomplete vehicle document):

- When adding a raised roof, do not remove the OEM roof structure forward of the B-pillar.
- To maintain cross-body stability, do not remove the last roof crossbow forward of the D-pillar.

WARNING Replace the original roof and roof bows only with structures of equal or greater strength.

- Before installing interior trim, conduct a water test to assure that there are no roof to body leaks.

! Refer to the Incomplete Vehicle Document for guidelines on excessive roof console vertical heights which will obscure the vision through the rearview mirror.

Body – Structure (cont'd)

Floorpan

CAUTION Some conversion procedures require perforating or otherwise modifying the floorpan. Use extreme caution when working near fuel lines, fuel tank, exhaust system, heat shields and moving chassis parts.

! Use templates to accurately locate holes and drill stops to limit the drilling depth.

- Do not place floor covering, such as carpeting, so that it extends past the engine cover seal area or interferes with engine cover mounting clamps to eliminate CO intrusion, water leaks and noise intrusion. (Figure 4.)

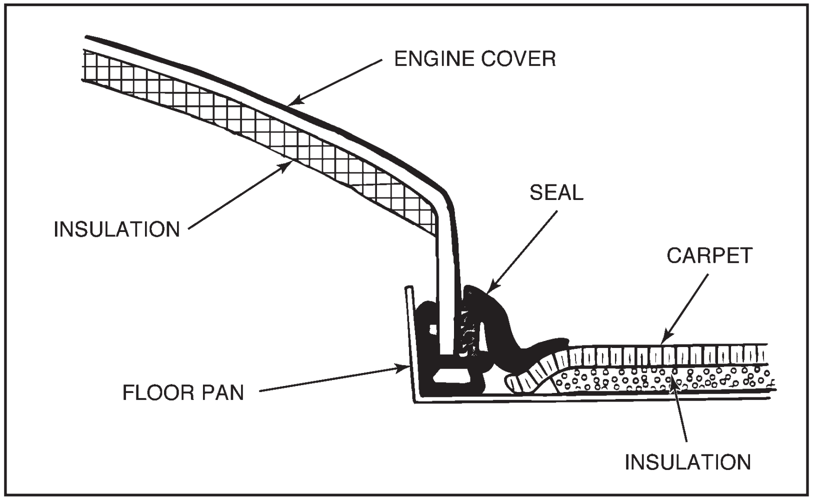

ENGINE COVER
INSULATION
SEAL
CARPET
FLOOR PAN
INSULATION

Figure 4

WARNING Use the proper reinforcements with rounded corners to anchor seat belts (Figure 5). This design helps to prevent "can-opening" of seat belt anchor plates and adjacent metal.

- Seal all holes in the floorpan to prevent carbon monoxide and water from entering the vehicle's interior. Conduct appropriate occupant compartment pressure testing to assure the effectiveness of floorpan seals.

  See the Upfitter Integration Paint and Sealing Guideline Manual.

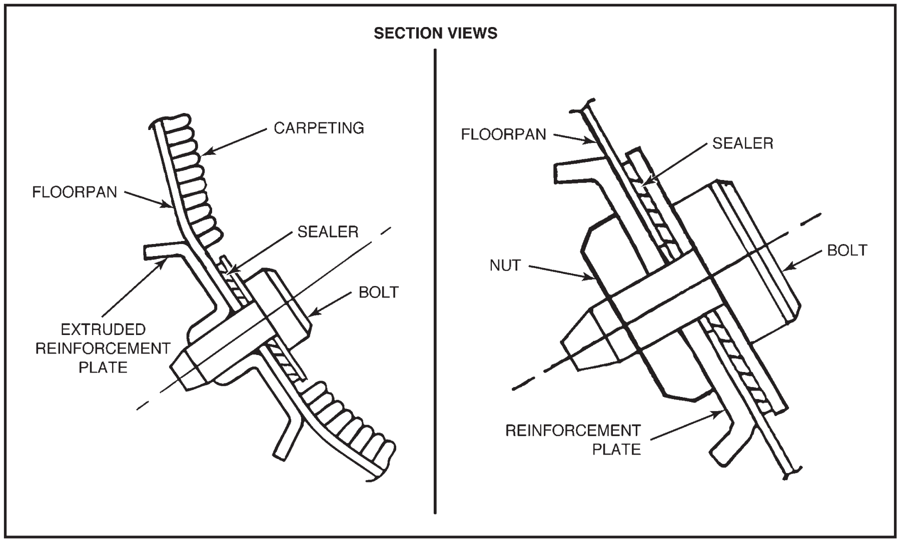

SECTION VIEWS
CARPETING
FLOORPAN
SEALER
BOLT
EXTRUDED REINFORCEMENT PLATE
FLOORPAN
SEALER
NUT
BOLT
REINFORCEMENT PLATE

Figure 5

WARNING Take particular care in performing the above procedures to assure that vehicle occupants are not exposed to exhaust fumes and carbon monoxide.

Body – Weatherstripping

WARNING Do not remove any body insulation, including thermal or underbody heat shields, provided by General Motors. OEM insulation protects the vehicle body and passengers from excessive heat and reduces noise levels. The floorpan of the finished vehicle must be covered by the OEM thermal insulation mat or equivalent replacement. The SVM must certify that all materials installed inside the passenger compartment comply with all applicable FMVSS standards (including FMVSS302 - Flammability of Interior Materials.)

Weatherstrip Installation

To properly install weatherstrip (door opening seal), follow the procedure below:

1. Install weatherstrip at corner A (Figure 6). Seat weatherstrip onto body flange on each side of the corner.
2. Drape and install weatherstrip at dot areas B through F.

! Attach the weatherstrip to the body flange in six areas to equally distribute weatherstrip length around the door opening.

3. Seat remaining weatherstrip onto the flange by hand between the installation points.
4. Final installation may require using a rubber mallet in thick flange areas, and in corners to fully seat the weatherstripping.

CAUTION When using a rubber mallet, be sure to hit the weatherstrip squarely to the flange. Doing otherwise may cause undesirable spreading of the carrier, resulting in reduced retention.

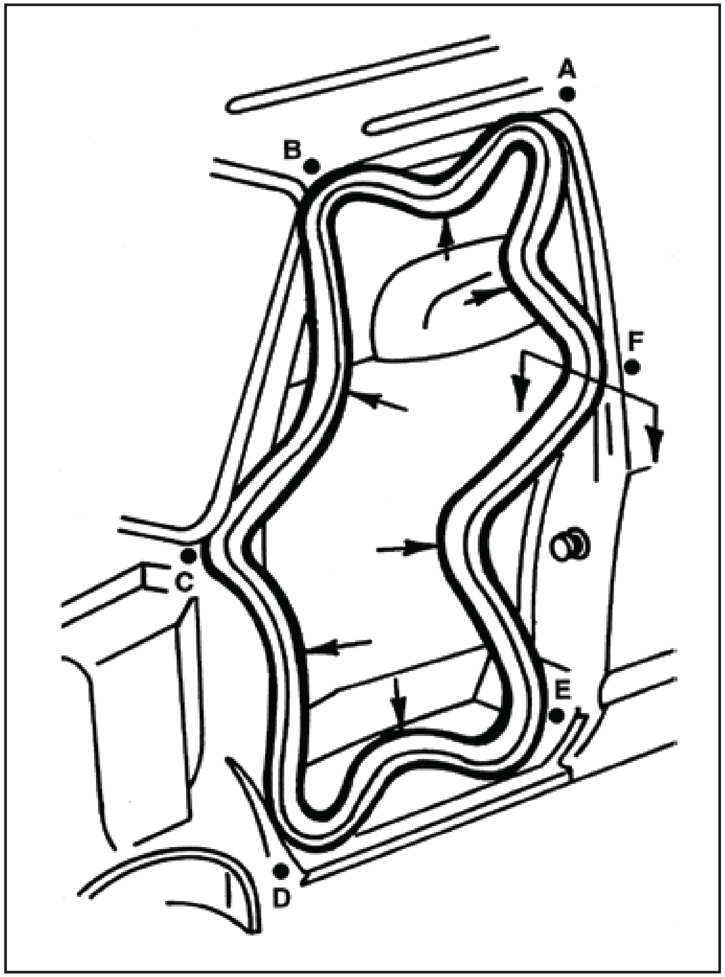


Figure 6

Body – Exterior Components

! If using door seals to retain the trim material, make sure the trim adheres to the flange and is closely trimmed on the outer surface of the flange to eliminate wicking water into passenger compartment. See Figure 7.

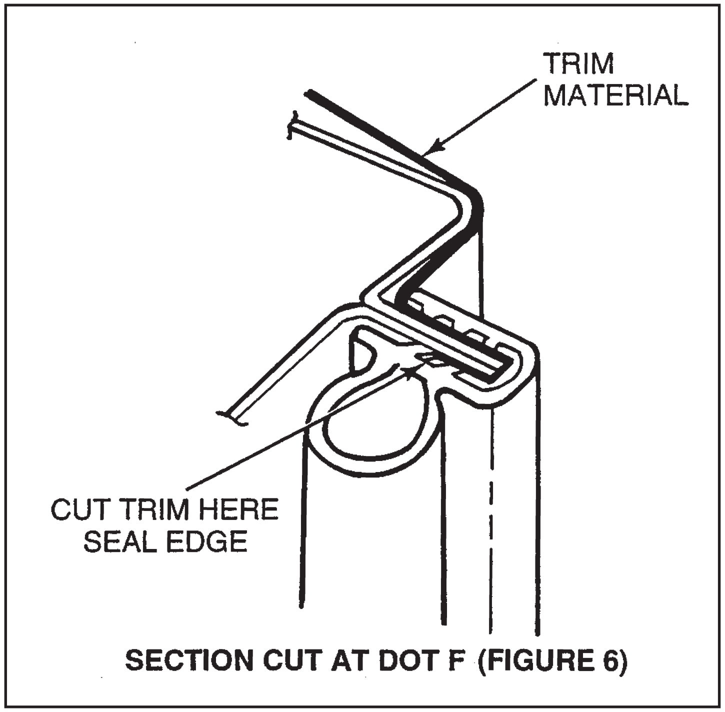


Figure 7

After installation is complete, inspect the weatherstrip for adherence to the following guidelines:

- **Corner fit** — The continuous corner should match the corner radius. Any rotation of the corner indicates that the fit is improper.
- **Proper seating** — The weatherstrip should be seated completely onto the flange in all areas, allowing the vinyl trim to lie smoothly around the entire door opening without waviness.
- **Carrier distortion** — Make sure that the carrier is free from distortion or spreading which may occur if it is hit improperly by a rubber mallet.
- **Secondary bulb** — The secondary sealing bulb should be continuously compressed on the body and door surfaces. Any areas of the weatherstrip with the bulb under the vinyl carrier should be removed and reinstalled.

Ladders, Spare Tire Carriers And Luggage Racks

When installing exterior components, it is important to align them properly. Include mounting pads to avoid damaging the paint or finish of the mounting surfaces. The following assembly procedures are recommended:

! Mating dissimilar metals may have a corrosive effect on the assembly. Always consider this condition when selecting materials that will have direct contact with the vehicle body.

CAUTION Do not attach spare tire carrier or ladders to vehicle's rear door. The door hinges are not designed to withstand this additional weight.

! Include proper labeling and instructions for the use of SVM-installed accessories with the finished vehicle.

Body – Exterior Components (cont'd)

Lower Body Treatments

CAUTION To assure minimum OEM ventilation requirements were met for the exhaust and brake systems, conduct heat transfer testing and analyses to be certain that added air dams or running boards do not degrade the vehicle’s airflow characteristics.

Do the same process to assure engine cooling and HVAC performance is within OEM minimum requirements.

Additional recommendations are:

- In order to provide sufficient clearance for steep driveway slopes, consider approach, departure and brakeover angles when designing lower body treatments.
- Do not remove or alter existing heat shields located on vehicle’s underbody.

WARNING Do not place mounting attachments for lower body treatments in locations that would affect the integrity of the fuel or braking systems during normal use or a collision.

- Fasten added components or attachment brackets to structural members, not to sheet metal. This reduces squeaks and rattles, and the possibility of distorting class “A” exterior body panels.
- Be sure to allow adequate clearances for OEM moving parts and exhaust system when designing or installing lower body treatments.
- Mount road and fog lamps to the underbody structure, not to fascia material. Doing so increases mounting stability and reduces vibration, noise and glare.

Running Boards

Strength and corrosive properties are key considerations in the selection of materials for runningboards.

WARNING Running boards should be capable of supporting a minimum static load of 500 pounds with less than 5mm of deflection. Installing components of lesser strength could result in damage to the supporting structure and human injury.

- Apply a protective coating to the running board attachment points to prohibit the corrosion.

General Motors also recommends the following:

- Attach the running board to a structural member of the body only, not to the frame. A combined frame and body mounting system will cause frame noise, vibration, and harshness transfer into the body.
- Conduct the appropriate checks to assure sufficient clearance between the wheel and running board (i.e., on bumpy roads and sharp turns). This is especially important when running boards are integral with the wheel opening lip.
- When installing a running board to the body of a pickup truck, a two-piece construction should be used. Attach the front piece to the cab and the rear piece to the box.
- When installing a step bar to the frame of a pickup truck, a one-inch minimum clearance should be maintained to the body.

Body – Interior Components

The purpose of added interior components is twofold: to provide occupant convenience as well as a visually appealing environment.

WARNING It is the SVM's responsibility to assure that all added interior components comply with all applicable FMVSS standards (including FMVSS201 - Occupant Protection in Interior Impacts and FMVSS302 - Flammability of Interior Materials.)

Additional recommendations are:

- Attach all load-bearing interior hardware to the body structure to assure mounting strength.
- Do not install components with sharp edges or protrusions that may potentially harm vehicle occupants.

! The minimum radius for corners on interior components is 3.2mm (International Standard).

- Consider the range of hand and finger motion when designing and selecting locations for passenger convenience items.
- Aim added interior lighting for optimum passenger convenience, maximum lighting effectiveness and to avoid disturbing the driver's vision.
- Include maintenance and operating instructions for all added interior components with the finished vehicle.

! For information on practices recommended by the Society of Automotive Engineers, refer to SAE documents J1048 (Symbols for Motor Vehicle Controls, Indicators and Tell-Tales) and J1139 (Direction-of-Motion Stereotypes for Automotive Hand Controls).

Headliner System

The headliner system is a high visibility item and must meet or exceed all customer expectations for fit, finish, function and quality. As previously noted, headliner systems must conform to all applicable FMVSS standards (including FMVSS201 - Occupant Protection in Interior Impacts and FMVSS302 - Flammability of Interior Materials.) General Motors expects SVMs to implement processes that guarantee product consistency and those that drive continuous improvement.

- The design should avoid gaps between the headliner and B-pillar and C-pillar garnish moldings, and roof garnish moldings.
- To assure mounting integrity, attach all loadbearing interior hardware (e.g., overhead console) to sheet metal that is well supported.

WARNING Avoid placing hidden sharp edges between the headliner and the roof panel. Doing so may result in injury to passengers and damage to the headliner.

Headliner system components should be serviceable without damage to the headliner. **Refer to GM service manuals for recommended disassembly procedures.**

Sun Visors

General Motors recommends using the OEM visors in the upfitted vehicle. SVMs may, however, retrim the original visor to match the vehicle's interior. Sun visors must comply with all applicable FMVSS standards (including FMVSS101 - Controls and Displays, FMVSS201 - Occupant Protection in Interior Impact and FMVSS302 - Flammability of Interior Materials.)

Refer to GM Specification GMW14231 for materials suitable for retrimming the sun visor.

Body – Interior Components (cont'd)

Floor Covering

! The floor covering system, which consists of carpeting, absorber and deadener material, must conform to all applicable FMVSS standards (including FMVSS302 - Flammability of Interior Materials.)

Carpeting

Install carpeting with a minimum weight of 18 oz. (i.e., 18 oz. Twilight). The minimum thickness for adequate carpet retention is 0.8" (20mm).

Choose carpeting that is free of loose threads, wrinkles, bubbles, frayed edges or attachment depressions. Also select materials that will lie flat against mating surfaces. Use only adhesives that are compatible with mating parts.

Sound Absorber and Deadener

Install sound-absorbing material wherever floor carpeting is added to a conversion vehicle.

- Use an insulator (deadener) with a sufficient thermal rating when it is exposed to higher exhaust system temperatures (see GM Specification GMW14231).
- Use a thermal cotton sound absorber to enhance interior acoustics (see GM Specification GMW14194).

Interior Trim Panels

Interior trim panels serve three important functions:

- Provides closeout for structural panels
- Secures other interior components
- Enhances the vehicle’s interior styling

WARNING Modifications should conform to the restrictions shown in “Incomplete Vehicle Document” in order to meet FMVSS occupant performance requirements. Like other interior components, trim panels must meet all applicable FMVSS standards (including FMVSS302 - Flammability of Interior Materials.)

Upfitters should also reference FMVSS 201, “Occupant Protection in Interior Impacts” for direction concerning interior fittings.

Plastic Trim Components

! Select plastic trim that is free of burrs, flash, mold-parting lines and sink marks. If plastic trim is grained, match the grade and grain direction of the components that are related to it.

Wood Trim Components

WARNING Round all wood-trim corners to eliminate sharp edges or protrusions that may result in passenger injury. The minimum radius for interior trim corners is 3.2mm.

! Avoid installing wood trim in areas exposed to direct sunlight. Over time, the sun’s ultraviolet rays will degrade the finish of the wood. All SVM-added decorative wood components should conform to GM Specification 2210M.

Body – Restraints and Seat Assemblies

Seating components and restraint systems must comply with all applicable FMVSS standards (including FMVSS201 - Occupant Protection in Interior Impact, FMVSS202 - Head Restraints, FMVSS207 - Seating Systems, FMVSS208 - Occupant Crash Protection, FMVSS209 - Seat Belt Assemblies, FMVSS210 - Seat Belt Assembly Anchorages and FMVSS302 - Flammability of Interior Materials.) Refer to the Incomplete Vehicle Document for additional information and requirements related to the systems and components discussed in this section.

The OEM restraint systems are designed to function properly with seating reference points and seat travel of the original equipment seats only. The non-OEM seats and belt systems that are installed by the SVM must be certified for compliance to FMVSS and CMVSS regulations.

Installation/Torque Specifications

! To assure compliance to federal regulations, torque all added seat and seat belt fasteners to specification.

WARNING Avoid altering shoulder belt attachment zones (location and the surrounding structure). Such modifications require FMVSS recertification.

Additional precautions:

- **For driver and front passenger seats and belts**

! Place seating reference points in locations identical to those specified in the “Incomplete Vehicle Document.”

— If, for any reason, it is necessary to remove OEM factory-installed front seat belts, reinstall them in their original positions using the proper tools. Torque all bolts to specification (see “Incomplete Vehicle Document”).

WARNING When drilling fastener holes through the floorpan, make sure that the fuel tank or fuel lines are not contacted. Use drill stops.

— Properly reinforce the floorpan at all fastener locations to avoid pull-through.

— Install backup washers under nuts at all locations.

WARNING Do not attach seat pedestals or seat belts through a layer of mat or carpeting. Doing so will cause compression of the material and result in a loss of torque.

WARNING All seat belt fasteners must be certified for compliance with FMVSS requirements.

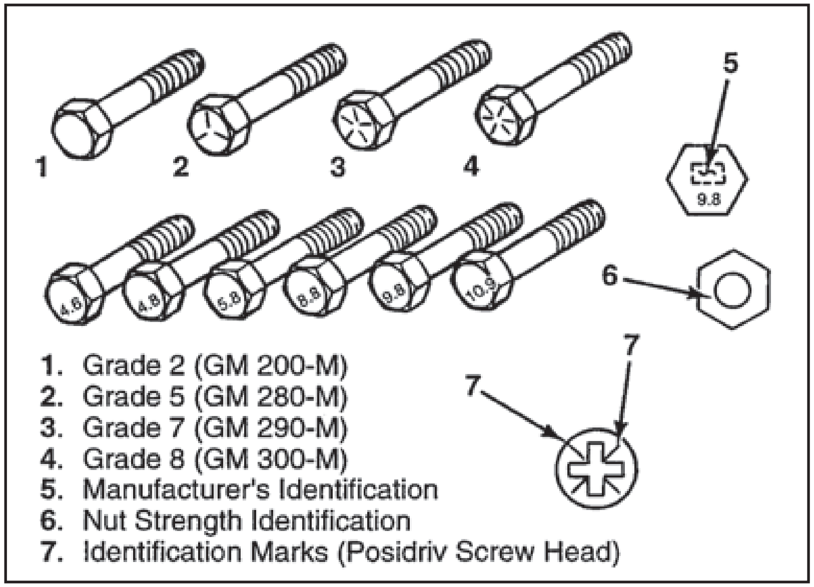
Body – Fasteners

The term “fastener” refers to bolts, nuts, washers, screws, rivets, pins, staples and other commonly used attaching parts. Most fasteners are metric, but are very close in dimension to common Englishsystem fasteners. Consideration should be given to the full range of available fasteners to assure the appropriate selection. This will help to reduce problems with squeaks, rattles, corrosion, fit and cosmetic appearance.

Metal Fasteners

! Always use fasteners that match the correct nominal diameter, thread pitch and strength of the mating part.

Original equipment metric fasteners, except “beauty” bolts (e.g., bumper bolts, cross-recess head screws), bear a marking on the head (Figure 8). This mark indicates the strength of the material making up the fastener.



1. Grade 2 (GM 200-M)
2. Grade 5 (GM 280-M)
3. Grade 7 (GM 290-M)
4. Grade 8 (GM 300-M)
5. Manufacturer's Identification
6. Nut Strength Identification
7. Identification Marks (Posidriv Screw Head)

Figure 8

Metric cross-recess screws are identified as “Posidriv” or “Type 1A.” Either a Phillips or Type 1A cross-recess screwdriver can be used in Posidriv recess screw heads, but Type 1A crossrecess screwdrivers perform better.

General Motors recommends the following fastener process guidelines:

! Purchase fasteners by part number rather than description to assure meeting the desired specifications.

- Use metric tapping screws incorporating Posidriv features on cross-recess heads.
- Use Posidriv nuts and bolts. They are designed to promote higher torquing ability and prevent slippage.
- Use metric, rather than English, fasteners. Never intermix metric and English fasteners (i.e., do not use English bolts with metric nuts, or vice versa). Also, use either all metric or all English fasteners within a vehicle system.
- Use self-drillers with milled (rather than forged) tips.
- Use hardened washers to assure consistent bearing surfaces. This allows positive sealing and is especially important in areas where gas and water may otherwise enter the vehicle.

WARNING Use a torque-control gun to install seat and seat belt bolts. Doing so will provide optimum control and proper torque.

For specific information on fasteners, refer to
Industrial Fastener Institute – www.indfast.org
American Society of Mechanical Engineers – www.ASME.org
International Association for Testing Materials – www.ASTM.org
Society of Automotive Engineers – www.SAE.org
See Appendix II for “General Fastener.

Body – Fasteners (cont'd)

Plastic Fasteners

Although there are many types, only three make up about 80 percent of all commonly used plastic fasteners. They are:

- Trees — Not recommended because of service issues that occur after reinstallation. They have a tendency to come loose and cause squeaks and rattles after service. This type of fastener is made up of “branches” (or arms), a “trunk” (stem) and a base (head). Trees can vary greatly from one another with different stems, different kinds of points and especially, different types of heads.
- Grommets — Sometimes called a nut or screw grommet, the grommet is installed in a hole or slot in one panel. The second component is then fastened by a screw through the second component into the grommet hole. Grommets are labeled according to the type of hole they fit (i.e., square, oval or round). They can be two- or four-legged. Always consider hole size and grip range when selecting grommets.
- Pushpins — Recommended fastener. Pushpins are basically grommets with a wedge attached to them and come in three types: basic pushpins, screw rivets and Rivet-RLoks. They are used by inserting the pushpin through the hole and then pushing the pin through to expand the legs and wedge it into place.

  Pushpins may be either crossed or noncrossed, depending on whether the legs are attached to each other at the tip. Screw rivets are similar to pushpins except they can be removed by unscrewing. Hole size and grip range are also important criteria when selecting this type of fastener.

Squeaks and Rattles

Because squeaks and rattles contribute greatly to customer dissatisfaction, it is important to recognize their possible causes and identify ways of eliminating them. The guidelines below can assist the SVM to develop designs that minimize or eliminate squeaks and rattles.

- Ideally, the part should not rattle when shaken. However, if the component’s function makes this impossible, hide or relocate the part and use sound-deadening material to isolate it.
- Design attachment brackets and adjacent parts with the following considerations:
  - — rigidity
  - — ability to self align during assembly
  - — clearance or interference fit
  - — temperature and environmental conditions
  - — surface and surrounding materials

! As much as possible, avoid cantilevered designs and components that cannot be positively attached.

- Preload moveable parts to restrict their movement.
- Secure components tightly in static state.

See APPENDIX III for related design and assembly principles that eliminate unwanted noise.

For specific information on fasteners, refer to
Industrial Fastener Institute – www.indfast.org
American Society of Mechanical Engineers – www.ASME.org
International Association for Testing Materials – www.ASTM.org
Society of Automotive Engineers – www.SAE.org
See Appendix II for “General Fastener.

Body – Appendix I

Welding Guidelines and Precautions

When welding anywhere on the vehicle, it is important to take precautionary measures to assure the safety of the technician and prevent damage to the vehicle or its systems, especially the electrical system wiring. General Motors recommends the following safety precautions:

- Every operator performing welding or cutting should wear goggles or masks designed for oxyacetylene work. Light from the oxyacetylene flame causes serious injury to the eyes, if unprotected.
- Use a friction lighter to light a welding torch. Never use matches, as doing so may result in burns, especially to the hand.
- Do not weld near or over cans, closed or empty. Flame from the welding torch can come into contact with fumes from the cans and result in an explosion.
- Never lay down a torch until the gases have been properly shut off.
- Hang torches only from hangers provided for that purpose.
- Keep the flame from coming into contact with hoses, regulators, cylinders, piping or any equipment. Failure to do so may result in fire.
- Do not set a hot piece of welding rod down where it can be picked up, stepped on or sat upon.
- When using a rod, bend the end over to eliminate any sharp points that may cause injury.
- To prevent leaks, make sure that regulators are firmly attached. Also take particular notice of the position of the thumbscrew and back it off until it spins with ease. When fastened to tanks or a line, regulators should be placed so that they do not interfere with valve operation in case of emergency.

WARNING Never use oil or grease on any part of the equipment or cylinders. Oil or grease, when combined with oxygen under pressure, will cause a violent explosion.

Additional welding precautions are:

- Before welding, remove or adequately shield any parts or components which could be damaged by excessive temperatures. Disconnect battery cables at the battery.
- Clean the area to be welded and the surrounding area of all frame-protective coating before welding.
- Place ground clamps as near as possible to the weld. This will eliminate stray current to vehicle components. Also use heavy gauge ground wire to a good building ground when welding.
- Open oxygen cylinder valves slowly so that the high-pressure gauge needle rises gradually, not with a jump. Continue to open the cylinder valve as far as it will go. Acetylene valves need only be opened to one-half turn.
- The hose's rubber covering burns easily. It is, therefore, important to keep the hose from coming into contact with hot, previously welded areas.
- After welding, allow parts to cool. Then carefully inspect wiring and electrical components for shortages or other damage which could draw excessive currents or cause an electrical system short when the battery is reconnected. Apply protective coating to areas from which coating was removed.

Body – Appendix I (cont'd)

Welding Guidelines and Precautions (cont'd)

Electrical System

! See the Upfitter Integration Electrical Best Practices: Electrical System Precautions section.

CAUTION To avoid damaging the OEM electrical system or components during welding procedures, GM recommends the following precautionary measures:

- Do not route welder electrical cables on, near or across any vehicle electrical wiring or components while welding is in progress.
- Remove or adequately shield any electrical or electronic components which can be damaged by excessive temperatures created by the welding operation.
- Protect all wiring and electrical components from damage that can be caused by welding flash (sparks).
- Make sure that the welder ground clamp is of an adequate size and placed as close as possible to the area being welded. Never use a vehicle suspension component as a welding ground point.
- Prior to any welding, disconnect all negative (ground) cable(s) from all battery(ies).
- Disable the air bag system as outlined in the “SIR Service Precautions” section of this manual.
- Disconnect any electrical/electronic computer modules located near the area to be welded. After welding is complete, carefully inspect any electrical wiring or components in the weld area for degradation or damage.

Body – Appendix II – General Fastener – Reference

Fastening To Thin Sheet Metal

Tapping screws have been a standard sheet metal attachment method for years. With the introduction of thinner gauges for cost and weight savings, new concerns became evident. Screws were stripping and loosening because the gauge now only allowed for 1/2 of a thread engagement. Extrusions did not help much because the extrusion wall, due to its thinness, would cut off instead of threading. The practical solution was the release of a new type of tapping screw, one which self extruded and rolled its own thread. This worked well but has shown itself to be somewhat operator sensitive. With the use of plant tooling at its present level of technology, this type of screw has had only moderate success.

Several other thin metal attachment fastening methods have been suggested. “Pop” rivets have always been a cost effective, fairly foolproof method of attaching joints that are in shear. The negative side is that the plants cannot seem to be able to install the parts effectively. Also loose mandrels are a common squeak and rattle complaint. Maintenance of the tool, proper pulling adjustment and periodic replacement of pulling jaws are usual reasons for poor performance of the tools.

The use of U-nuts, another often suggested method of attachment, is not always desirable. Clearance for the legs, installation slots or nearness to a flat edge, ergonomic considerations such as push-on effort, parts count increase, parts falling off or moving aside, are some of the problems encountered when using U-nuts in attachments. While the parts are used today, their shortcomings are carefully considered.

Various snap-ins, plastic as well as steel, do not function well in sheet metal joints, which are mostly in shear. Welding is a possibility, but leaves unsightly appearances. Even when weld attachments are done prior to paint, the weld depression is not acceptable on most visible surfaces.

An analysis of the root cause of the problem indicates that the correct solution is to thicken the attachment point. This can be done with the use of welded nuts (negatives are high cost of assembly, energy, labor, handling, poor tolerancing); pierce nuts installed in the stamping process (cost effective, but needs space for the physical dimensions of the part and installation tool clearances); the use of tapping plates (cost of energy, tolerances may be a concern); or the use of a snap-in type spring nut. The snap-in type spring nut, when used with a tapping screw, has been shown to be an effective, high-strength joint requiring little physical space, easily installed and relatively inexpensive.

Although tapping screws present some difficulties, their use cannot be totally eliminated. When used with metal-to-metal interfaces such as the snap-in nuts or other joint “thickeners” (i.e., tapping plates), they can effectively be a robustly designed attachment.

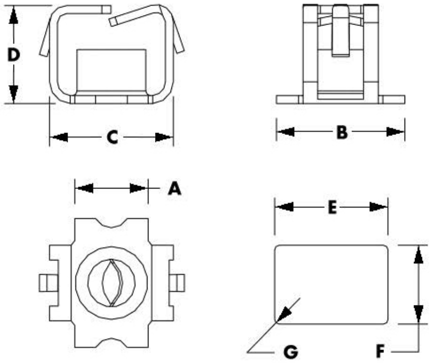
Body – Appendix II – General Fastener – Reference (cont'd)

Expansion Nuts – Box Style (Multi-Threaded)

Material:
Spring Steel per SAE J403 Grade 1050-1065

NOTES

- 4.2 sizes are recommended for Sheet Metal panels 0.5 – 5.0 mm thick with 4.2 X 1.41 Tapping Screws.
- DO NOT USE 4.2 or M6 NUTS IN PLASTIC PANELS. DO NOT USE M6 IN SOFT ALUMINUM OR MAGNESIUM.
- Multi-threaded Nuts are Preferred over Single impression threaded Nuts (i.e. Better Squeak and Rattle Performance).
- Typical Applications include: Fascia's, Tail lamps, Wheel Liners, Trim, Underbody panels, and Speakers.
- Push nuts, found on this catalog page, not recommended for installation in body shop. Covers up base metal and prevents base metal ELPO coverage.



RECOMMENDED HOLE DIMENSIONS
(AFTER ALL APPLIED FINISHES)

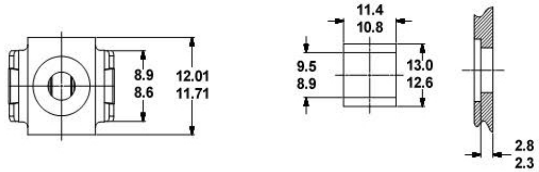
Thread / Pitch	Grip Range	Seal (Y/N)	A max	B max	C nom	D nom	E max	F max	G max
4.2 x 1.41	0.5 – 2.3	N	6.8	16.2	8.4	6.9	8.75	8.75	0.60
4.2 x 1.41	0.5 – 2.3	Y	6.8	16.2	8.4	6.9	8.75	8.75	0.60
4.2 x 1.41	1.4 – 5.0	N	14.0	24.5	10.8	9.9	16.2	11.2	1
M6 x 1.00	0.7 – 3.8	N	8.5	18.5	13.35	10.8	14.03	9.53	0.50
M6 x 1.00	0.7 – 2.0	Y	8.7	14.5	13.5	10.7	14.03	9.53	0.50

Expansion Nuts – Robotics Style (Multi-Threaded)

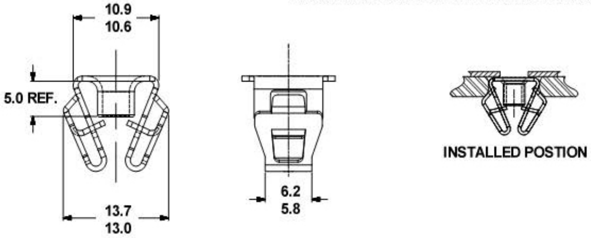
Material:
Spring Steel per SAE J403 Grade 1050-1065 Hardness R30N64-70

NOTES

- Recommended for Plastic panels with 4.2 X 1.41 Tapping Screws.
- Multi-threaded Nuts are Preferred over Single impression threaded Nuts (i.e. Better squeak and Rattle Performance).
- Typical Applications include: I/P Carriers, Fascia's, and Wheel Flares.
- If the panel thickness is greater than 2.80, then the step is required as shown below.



RECOMMENDED LAYOUT IN PLASTIC PANELS



INSTALLED POSTION

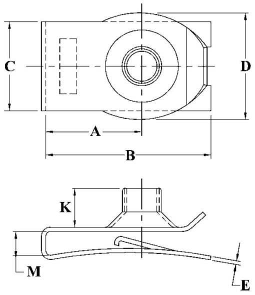
Body – Appendix II – General Fastener – Reference (cont'd)

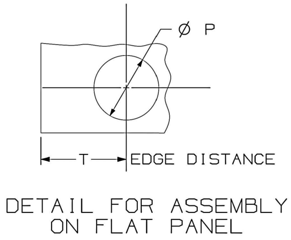
U-Nuts - Multithread

Material:
SAE J403 Grade 1050-1065
Hardness: <M6 HR30N 59.5 - 68.5, >M6 HRC 42 - 50

NOTES

- M10 & M8 parts are not recommended for use against plastic.
- Style I is preferred.
- Recommended for use with 4.2 X 1.41 screws.
- U-Nuts provide support to both sides of the mating panel and can be used on plastic or sheet panels.
- Multi-threaded Nuts are Preferred over Single impression and plastic nut members (Improved Squeak and Rattle Performance).
- Typical Applications include but are not limited to: interior and exterior trim panels to structure, consoles, instrument panel, fascia, tail lamp, and wheelhouse liners.





Recommended Hole Dimensions

U-Nuts - Multithread (continued)

Size	Panel Thickness Range	PT	Throat Type	A Throat Depth	B Leg Length	C Leg Width 1	D Leg Width 2	E Stock Thickness		K Barrel Height		M Width At Fold		P Diameter		T Panel Edge
				+/- 0.5	+/- 0.5	+/- 0.5	+/- 0.5	max	min	max	min	max	min	max	min	+/- 0.5
4.2	0.5 - 2.0	Y	Style I	10.16	17.3	10.5	12.5	0.69	0.61	6.1	5.1	2.5	2.2	7.75	7.55	7.6
4.2	2.0 - 3.0	Y	Style I	9.6	16.8	"	"	"	"	"	"	3.5	3.2	"	"	"
4.2	0.65 – 3.8	Y	Style II	15.0	22.0	"	"	0.66	0.56	"	"	4.5	4.0	"	"	13.5
M6	0.8 - 4.0	N	Style I	13.5	23.5	12.5	14.5	0.90	0.70	6.5	5.5	5.2	3.2	10.1	9.9	12.0
"	0.8 - 4.0	Y	Style I	“	“	“	“	“	“	“	“	“	“	“	“	“
"	0.8 - 4.0	N	Style II	19.5	29.5	"	"	"	0.80	"	"	"	4.2	"	"	18.0
"	2.0 - 5.0	N	Style I	13.5	23.5	"	"	"	"	"	"	6.2	5.2	"	"	12.0
"	2.0 - 5.0	N	Style II	19.5	29.5	"	"	"	"	"	"	"	"	"	"	18.0
M8	0.8 - 4.0	N	Style I	14.5	25.0	14.2	17.0	1.10	1.00	9.0	7.5	5.2	3.2	11.5	11.3	13.0
"	0.8 - 4.0	N	Style II	21.0	31.5	"	"	"	"	"	"	"	4.2	"	"	19.5
"	2.0 - 5.0	N	Style I	14.5	25.0	"	"	"	"	"	"	6.2	5.2	"	"	13.0
"	2.0 - 5.0	N	Style II	21.0	31.5	"	"	"	"	"	"	"	"	"	"	19.5
M10	1.5 – 5.5	N	Style I	18.5	32.5	17.5	24.0	1.45	1.35	10.5	9.0	6.7	5.7	15.5	14.7	17.0
"	1.5 – 5.5	N	Style II	28.5	43.0	"	"	"	"	10.5	9.5	"	"	"	"	27.0
"	3.0 - 6.0	Y	Style I	18.5	32.5	17.5	23.9	"	"	10.2	9.2	7.7	6.6	15.6	15.1	15.6

PT = Prevailing torque, crimp type

Body – Appendix II – General Fastener – Reference (cont'd)

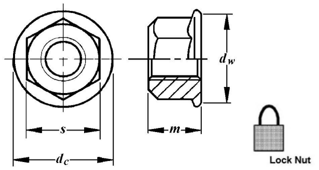
Hexagon Flange Nuts All-Metal Prevailing Torque

Material:
ISO 2320 (10)

NOTES

- For general applications, the Best Practice is to use All-Metal Prevailing Torque Nuts where prevailing torque nuts are required.
- All-metal prevailing torque (AMPT) nut usage guidelines:
  - Use AMPT nuts as a first choice, and use nylon ring/nylon patch nuts as an exception.
  - AMPT nuts can be used at higher temperatures than nylon ring/nylon patch nuts. Nylon ring/nylon patch nuts shall not be used when the nut temperature exceeds 120°C/248°F.
  - AMPT nuts can be used where higher prevailing on and off torques are required as compared to nylon ring/nylon patch nuts are required.
  - AMPT nuts should be used in safety critical joints where more warning of loosening is desired.
  - Do not use AMPT nuts on applications where thread galling will occur. Use nylon ring/nylon patch nuts on these applications.
- Nylon insert prevailing torque nuts should be used on an exception basis in the following applications:
  - Where consistent drive torques are required.
  - Where heavy or inconsistent paint build-up or overspray occur.
  - Where long rundowns (over 7 revolutions) occur.
  - In brake booster and steering column joints.
  - Where the externally threaded part has no finish.

  Where temperature in service is greater than -70°C and less than 120°C.



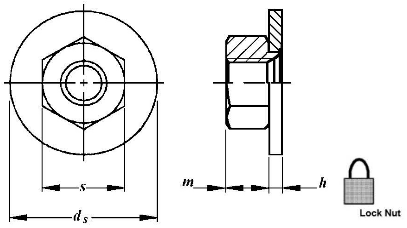
Thread / Pitch	s max	m max	d_c max	d_w min
M6 x 1.0	10.0	7.3	14.2	12.2
M8 x 1.25	13.0	9.4	17.9	15.8
M10 x 1.5	15.0	11.4	21.8	19.6
M12 x 1.75	18.0	13.8	26.0	23.8
M14 x 2.0	21.0	15.9	29.9	27.6
M16 x 2.0	24.0	18.3	34.5	31.9

AMPT Hexagon Nut and Washer Assemblies with Flat Washer

Material:
ISO2320 (10)

NOTES

- These nuts are recommended for use against soft surfaces, e.g. painted sheet, plastic etc.
- All-metal prevailing torque (AMPT) nut usage guidelines:
  - Use AMPT nuts as a first choice, and use nylon ring/nylon patch nuts as an exception
  - AMPT nuts can be used at higher temperatures than nylon ring/nylon patch nuts. Nylon ring/nylon patch nuts shall not be used when the nut temperature exceeds 120°C/248°F
  - AMPT nuts can be used where higher prevailing on and off torques are required as compared to nylon ring/nylon patch nuts are required.
  - AMPT nuts should be used in safety critical joints where more warning of loosening is desired.
- Do not use AMPT nuts on applications where thread galling will occur. Use nylon ring/nylon patch nuts on these applications.



Thread / Pitch	s max	m max	h max	d_s max
M6 x 1.0	10.0	5.7	2.00	19.0
M8 x 1.25	13.0	7.5	2.60	24.0

Body – Appendix II – General Fastener – Reference (cont'd)

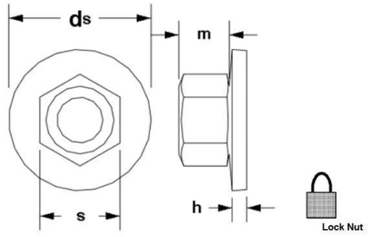
AMPT Hexagon Nut and Washer Assemblies with Conical Washer

Material:
ISO2320 (10)

NOTES

- All-metal prevailing torque (AMPT) nut usage guidelines:
  - Use AMPT nuts as a first choice, and use nylon ring/nylon patch nuts as an exception.
  - AMPT nuts can be used at higher temperatures than nylon ring/nylon patch nuts. Nylon ring/nylon patch nuts shall not be used when the nut temperature exceeds 120°C/248°F.
  - AMPT nuts can be used where higher prevailing on and off torques are required as compared to nylon ring/nylon patch nuts are required.
  - AMPT nuts should be used in safety critical joints where more warning of loosening is desired.
  - Do not use AMPT nuts on applications where thread galling will occur. Use nylon ring/nylon patch nuts on these applications.

These nuts are not recommended for use against soft surfaces, e.g. plastic etc. Use a nut with flat washer instead.

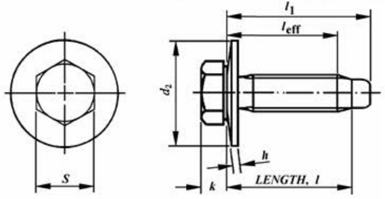


Thread / Pitch	s hex	m max	d_s max	h max
M6 x 1.0	10.0	5.70	19.0	2.00
M8 x 1.25	13.0	7.50	19.0	2.60
M8 x 1.25	13.0	7.50	24.0	2.60
M10 x 1.5	15.0	9.30	28.0	3.05
M12 x 1.75	18.0	12.00	28.0	3.20
M14 x 2.0	21.0	14.10	32.0	3.45
M14 x 2.0	21.0	14.10	40.0	3.45
M16 x 2.0	24.0	16.40	36.0	4.05
M16 x 2.0	24.0	16.40	40.0	4.05

Hex Screw and Washer Assemblies with Conical Washer and M-Point

NOTES

- Hex flange bolts are recommended for use in most applications.
- These fasteners should only be used against hard surfaces (e.g. steel) and when needed to cover clearance holes.
- These fasteners should not be used against soft surfaces (e.g. plastic, aluminum).



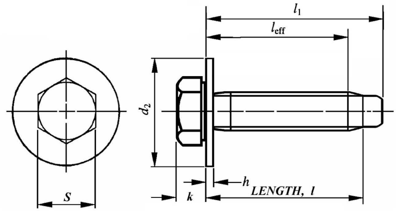
Thread		M6			M8			M10			M12		
P	Pitch	1			1.25			1.5			1.75		
s	Hex	10			13			15			18		
k	max	4.15			5.45			6.58			7.68		
h	max	2.12			2.63			3.15			3.55		
d_2	max	17			24			28			35		
l nom		l_1 max	l_{eff} min		l_1 max	l_{eff} min		l_1 max	l_{eff} min		l_1 max	l_{eff} Min	
12		15.0	9.55										
16		19.0	13.55		20.05	13.05							
20		23.0	17.55		24.05	17.05		24.8	16.45				
25		28.0	22.55		29.05	22.05		29.8	21.45		30.8	20.85	
30		33.0	27.55		34.05	27.05		34.8	26.45		35.8	25.85	
35					39.05	32.05		39.8	31.45		40.8	30.85	
40					44.05	37.05		44.8	36.45		45.8	35.85	
45					49.05	42.05		49.8	41.45		50.8	40.85	
50					54.05	47.05		54.8	46.45		55.8	45.85	
55					59.15	51.95		59.9	51.35		60.9	50.75	
60											65.9	55.75	
65											70.9	60.75	
70								75.05	66.50		75.9	65.75	
80								85.1	76.35		85.9	75.75	
85											90.9	80.75	11570800

Body – Appendix II – General Fastener – Reference (cont'd)

Hex Screw and Washer Assemblies with Flat Washer and M-Point

NOTES

- This fastener is recommended for use against soft surfaces. (e.g. plastic, aluminum)
- For screws with washers with d2 of 24.00mm the recommended maximum clearance hole is 15mm.
- Hex flange bolts are recommended for use in most applications.

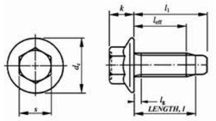


Thread / Pitch	Property Class	l nom	l_1 max	l_{eff} min	S max	k max	h max	d_2 max
M6 x 1.0	8.8	12.0	15.0	9.55	10.0	4.15	1.68	17.00
M6 x 1.0	8.8	16.0	19.0	13.55	10.0	4.15	1.68	17.00
M6 x 1.0	8.8	16.0	19.0	13.55	10.0	4.15	2.30	24.00
M6 x 1.0	8.8	20.0	23.0	17.55	10.0	4.15	1.68	17.00
M6 x 1.0	8.8	20.0	23.0	17.55	10.0	4.15	2.30	24.00
M6 x 1.0	8.8	25.0	28.0	22.55	10.0	4.15	1.68	17.00
M6 x 1.0	8.8	25.0	28.0	22.55	10.0	4.15	2.30	24.00
M6 x 1.0	8.8	30.0	33.0	27.55	10.0	4.15	1.68	17.00
M6 x 1.0	8.8	30.0	33.0	27.55	10.0	4.15	2.30	24.00
M6 x 1.0	8.8	35.0	38.0	32.55	10.0	4.15	1.68	17.00
M6 x 1.0	8.8	35.0	38.0	32.55	10.0	4.15	2.30	24.00
M6 x 1.0	8.8	40.0	43.0	37.55	10.0	4.15	1.68	17.00
M6 x 1.0	8.8	40.0	43.0	37.55	10.0	4.15	2.30	24.00
M6 x 1.0	8.8	45.0	48.0	42.55	10.0	4.15	1.68	17.00
M8 x 1.25	8.8	26.6	30.7	23.70	13.0	5.45	2.09	24.0
M8 x 1.25	8.8	30.0	34.05	27.05	13.0	5.45	2.63	32.0
M8 x 1.25	9.8	36.45	40.5	32.50	13.0	5.50	2.80	32.0
M8 x 1.25	10.9	39.95	44.0	37.00	13.0	6.00	2.30	24.0
M8 x 1.25	8.8	55.0	59.05	52.05	13.0	5.45	2.20	24.0

GENERAL USE FASTENERS:
BOLTS AND SCREWS:
Heavy Hexagon Flange Bolts with M-Point, Full Body, Radius Head (Acorn)

NOTES

- Parts above the continuous red thick stepped line are threaded to the head. For M6, M8, and M10 Applications use Heavy Hexagon Flange Bolts with M-Point, Full Body, Radius Head (Acorn).

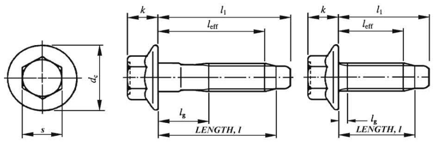


Thread		M6				M8				M10			
P		1.0				1.25				1.5			
s	Hex	10				13				15			
k	max	6.6				8.1				10.4			
d_c	max	14.2				18				22.3			
l		*l*	l_1	l_{eff}	l_g	*l*	l_1	l_{eff}	l_g	*l*	l_1	l_{eff}	l_g
(ref)		nom	max	min	max	nom	max	min	max	nom	max	min	max
10		7.65	10.65	5.2	1.5								
13		10.65	13.65	8.2	1.5								
16		13.65	16.65	11.2	1.5								
20		17.65	20.65	15.2	1.5	16.65	20.70	13.7	1.9	15.85	20.65	12.3	2.2
25		22.65	25.65	20.2	2.5	21.65	25.70	18.7	1.9	20.85	25.65	17.3	2.2
30		27.65	30.65	25.2	2.5	26.65	30.70	23.7	3.1	25.85	30.65	22.3	2.2
35		32.65	35.65	30.2	12.5	31.65	35.70	28.7	3.1	30.85	35.65	27.3	3.8
40		37.65	40.65	35.2	17.5	36.65	40.70	33.7	12.0	35.85	40.65	32.3	3.8
45		42.65	45.65	40.2	22.5	41.65	45.70	38.7	17.0	40.85	45.65	37.3	11.5
50		47.65	50.65	45.2	27.5	46.65	50.70	43.7	22.0	45.85	50.65	42.3	16.5
55		52.65	55.75	50.1	32.5	51.65	55.80	48.6	27.0	50.85	55.75	47.2	21.5
60		57.65	60.75	55.1	37.5	56.65	60.80	53.6	32.0	55.85	60.75	52.2	26.5
65		62.65	65.75	60.1	32.5	61.65	65.80	58.6	37.0	60.85	65.75	57.2	31.5
70		67.65	70.75	65.1	47.5	66.65	70.80	63.6	42.0	65.85	70.75	62.2	36.5
75		72.65	75.75	70.1	42.5	71.65	75.80	68.6	45.0	70.85	75.75	67.2	41.5
80		77.65	80.75	75.1	57.5	76.65	80.80	73.6	52.0	75.85	80.75	72.2	46.5
85		82.65	85.75	80.1	52.5	80.00	84.15	77.0	52.0	80.85	85.75	77.2	51.5
90		87.65	90.75	85.1	67.5	86.65	90.80	83.6	62.0	85.85	90.75	82.2	56.5
95		91.85	94.95	89.3	62.6	91.65	95.80	88.6	67.0	90.85	95.75	87.2	61.5
100						96.65	100.80	93.6	72.0	95.85	100.75	92.2	66.5
105						100.85	105.00	97.8	76.2	100.85	105.75	97.2	71.5
110		107.65	110.75	105.1	87.5	105.00	109.15	101.9	83.0	105.85	110.75	102.2	76.5
115		112.65	115.75	110.1	87.0	111.65	115.80	108.6	87.0	110.85	115.75	107.2	81.5
120						116.65	120.80	113.6	92.0	115.85	120.75	112.2	86.5
125						122.65	126.80	119.6	98.0	120.85	125.75	117.2	91.5

Body – Appendix II – General Fastener – Reference (cont'd)

Heavy Hexagon Bolts with Flange and M-Point M12, M14, M16

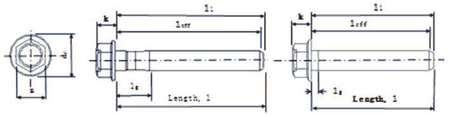
NOTES
- Parts above the continuous red thick stepped line are threaded to the head. For M12, M14, and M16 Applications Use Heavy Hexagon Bolts with Flange and M-Point.



Thread		M12				M14				M16			
P	Pitch	1.75				2				2			
s	Hex	18				21				24			
k	max	11.8				13.7				15.4			
d_c	max	26.6				30.5				35			
l		l_1	l_{eff}	l_g		l_1	l_{eff}	l_g		l_1	l_{eff}	l_g	
nom		max	min	max		max	min	max		max	min	max	
25		30.8	20.85	2.6									
30		35.8	25.85	4.4		36.58	25.35	3					
35		40.8	30.85	4.4		41.58	30.35	5		42.25	30.35	3	
40		45.8	35.85	4.4		46.58	35.35	5		47.25	35.35	5	
45		50.8	40.85	4.4		51.58	40.35	5		52.25	40.35	5	
50		55.8	45.85	4.4		56.58	45.35	5		57.25	45.35	5	
55		60.9	50.75	4.4		61.68	50.25	5		62.35	50.25	5	
60		65.9	55.75	4.4		66.68	55.25	5		67.35	55.25	5	
65		70.9	60.75	4.4		71.68	60.25	5		72.35	60.25	5	
70		75.9	65.75	21.0		76.68	65.25	5		77.35	65.25	5	
75		80.9	70.75	26.0		81.68	70.25	5		82.35	70.25	5	
80		85.9	75.75	31.0		86.68	75.25	27		87.35	75.25	5	
85		90.9	80.75	36.0		91.68	80.25	32		92.35	80.25	5	
90		95.9	85.75	41.0		96.68	85.25	37		97.35	85.25	33	
95		100.9	90.75	46.0		101.68	90.25	42		102.35	90.25	38	
100		105.9	95.75	51.0		106.68	95.25	47		107.35	95.25	43	
105		110.9	100.75	56.0		111.68	100.25	52		112.35	100.25	48	
110		115.9	105.75	61.0		116.68	105.25	57		117.35	105.25	53	
115		120.9	110.75	66.0		121.68	110.25	62		122.35	110.25	58	
120		125.9	115.75	71.0		126.68	115.25	67		127.35	115.25	63	
125		130.9	120.75	76.0		131.68	120.25	72		132.35	120.25	68	
130		135.9	125.75	81.0		136.68	125.25	77		137.35	125.25	73	
135		140.9	130.75	86.0		141.68	130.25	82		142.35	130.25	78	
140		145.9	135.75	91.0		146.68	135.25	87		147.35	135.25	83	
145						151.68	140.25	105					
150		155.9	145.75	71.0		156.68	145.25	97		157.35	145.25	93	
155		160.9	150.75	120.0									
160		165.9	155.75	91.0						167.35	155.25	103	

Heavy Hexagon Bolts with Flange and Header Point

NOTES
- **Header point bolts are intended for use in hand starting applications only.**
- Parts above the continuous red thick stepped line are threaded to the head.
- Reduced shank type only below the dashed line. If no dashed line on a diameter, parts below red line are also reduced shank.



Thread		M10				M12				M14				M16			
P	Pitch	1.5				1.75				2				2			
S	Hex	15				18				21				24			
K	max	10.4				11.8				13.7				15.4			
d_c	max	22.3				26.6				30.5				35			
l		l_1	l_{eff}	l_g		l_1	l_{eff}	l_g		l_1	l_{eff}	l_g		l_1	l_{eff}	l_g	
nom		max	min	max		max	min	max		max	min	max		max	min	max	
16		16.4	13.35	2.2													
20		20.4	17.35	2.2													
25		25.4	22.35	3.8		25.4	22.18	4.4									
30		30.4	27.35	3.8		30.4	26.98	4.4		30.4	25.6	3					
35		35.5	32.25	3.8		35.8	31.58	4.4		35.8	30.2	5		35.8	30.2	3	
40		40.8	37.25	3.8		40.8	36.58	4.4		40.8	35.2	5		40.8	35.2	5	
45		45.8	42.25	3.8		45.8	40.7	4.4		45.8	40.2	5		45.8	40.2	5	
50		50.8	47.25	3.8		50.8	45.7	4.4		50.8	45.2	5		50.8	45.2	5	
55		56.0	52.15	3.8		56.0	50.5	4.4		56.0	50.0	5		56.0	50.0	5	
60		61.0	57.15	3.8		61.0	55.5	4.4		61.0	55.0	5		61.0	55.0	5	
65		66.0	62.15	11.5		66.0	60.5	4.4		66.0	60.0	5		66.0	60.0	5	
70		71.0	67.15	16.5		71.0	65.5	4.4		71.0	65.0	5		71.0	65.0	5	
75		76.0	72.15	21.5		76.0	72.5	4.4		76.0	70.0	5		76.0	70.0	5	
80		81.0	77.15	26.5		81.0	75.5	4.4		81.0	75.0	5		81.0	75.0	5	
85		86.1	82.05	31.5		86.1	80.4	4.4		86.1	79.9	5		86.1	79.9	5	
90		91.1	87.05	36.5		91.1	85.4	21		91.1	84.9	5		91.1	84.9	5	
95		96.1	92.05	41.5		96.1	90.4	26		96.1	89.9	5		96.1	89.9	5	
100		101.1	97.05	46.5		101.1	95.4	31		101.1	94.9	27		101.1	94.9	5	
105		106.1	102.05	51.5		106.1	100.4	36		106.1	99.9	32		106.1	99.9	5	
110		111.1	107.05	56.5		111.1	105.4	41		111.1	104.9	37		111.1	104.9	33	
115		116.1	112.05	61.5		116.1	110.4	46		116.1	109.9	42		116.1	109.9	38	
120		121.1	117.05	66.5		121.1	115.4	51		121.1	114.9	47		121.1	114.9	43	
125		126.3	121.95	71.5		126.3	120.2	56		126.3	119.7	52		126.3	119.7	48	
130						131.3	125.2	61		131.3	124.7	57		131.3	124.7	53	
135						136.3	130.2	66		136.3	129.7	62		136.3	129.7	58	
140						141.3	135.2	71		141.3	134.7	67		141.3	134.7	63	
150										151.3	144.7	77		151.3	144.7	73	
160														161.3	154.7	83	

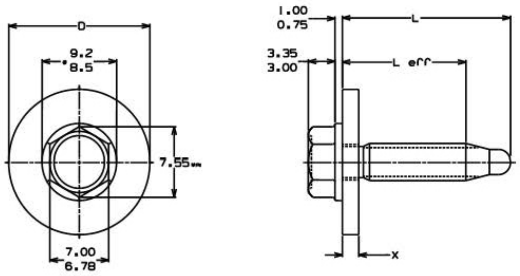
Body – Appendix II – General Fastener – Reference (cont'd)

M4.2 Hex Washer Head Tapping Screw Assembly with Flat Washer BR Point

Material:
ISO 2702

NOTES

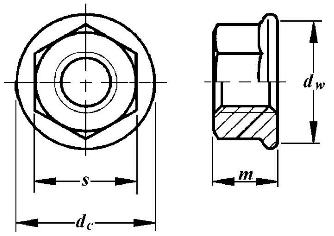
- To be used with Multi-Threaded U-nuts & Expansion Type Nuts.
- Fastening directly into plastic is not a recommended practice for a robust attachment.
- The recommended clearance holes are 5.0 mm diameter for Regular series washers, and 8.0mm diameter for Wide series washers.
- Not to be used for structural attachments.



Thread / Pitch	Series	D		X		L			L eff
		min	max	min	max	nom	min	max	min
M4.2 x 1.41	Regular	12.07	12.50	1.0	1.4	13	12.2	13.8	7.2
M4.2 x 1.41	Regular	12.07	12.50	1.0	1.4	16	15.2	16.8	10.2
M4.2 x 1.41	Regular	12.07	12.50	1.0	1.4	20	19.2	20.8	14.2
M4.2 x 1.41	Regular	12.07	12.50	1.0	1.4	25	24.2	25.8	19.2
M4.2 x 1.41	Regular	12.07	12.50	1.0	1.4	30	28.7	31.3	23.7
M4.2 x 1.41	Regular	12.07	12.50	1.0	1.4	35	33.7	36.3	28.7
M4.2 x 1.41	Wide	16.57	17.00	1.6	2.3	16	15.2	16.8	10.2
M4.2 x 1.41	Wide	16.57	17.00	1.6	2.3	20	19.2	20.8	14.2
M4.2 x 1.41	Wide	16.57	17.00	1.6	2.3	25	24.2	25.8	19.2
M4.2 x 1.41	Wide	16.57	17.00	1.6	2.3	30	28.7	31.3	23.7

Hexagon Nuts with Flange

Material:
ISO 898-2 (8 ≤M8, 10 ≥M10)



Thread / Pitch	s hex	d_c max	d_w min	m max
M6 x 1.00	10.0	14.2	12.2	6.0
M8 x 1.25	13.0	17.9	15.8	8.0
M10 x 1.50	15.0	21.8	19.6	10.0
M12 x 1.75	18.0	26.0	23.8	12.0
M14 x 2.00	21.0	29.9	27.6	14.0

Body – Appendix II – General Fastener – Reference (cont'd)

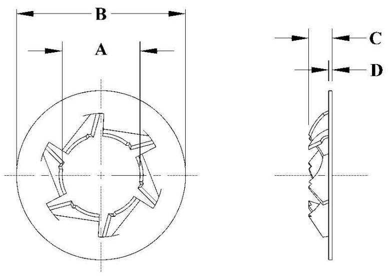
RETAINERS:

Retainer

Material:

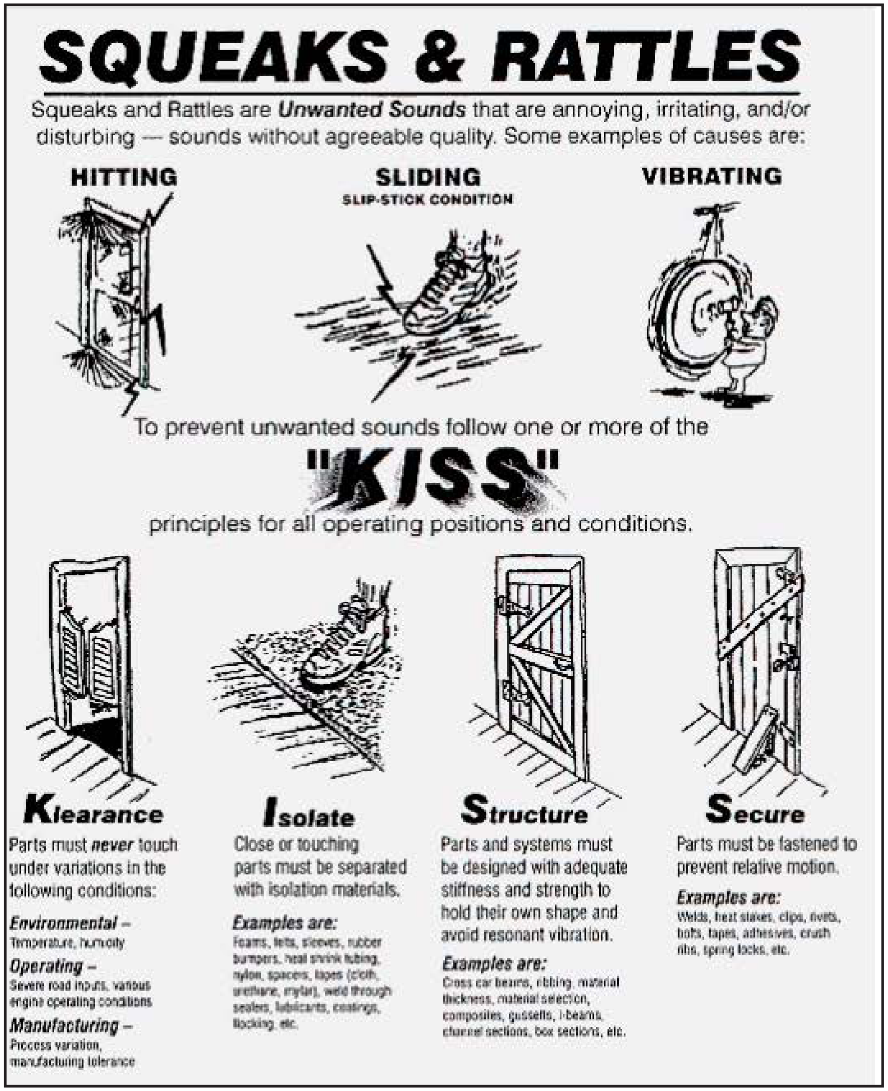
SAE J403 Grade 1050 min

NOTES • Generally used to temporarily retain fasteners during shipping and assembly.



Thread / Pitch	A		B		C		D		Purpose
	Inside Diameter		Outside Diameter		Overall Thickness		Stock Thickness		
	max	min	max	min	max	min	max	min	
M6 x 1.00	5.40	5.10	12.95	12.45	2.43	1.93	0.270	0.230	General
M6 x 1.00	5.40	5.10	12.95	12.45	2.43	1.93	0.270	0.230	Grounding
M8 x 1.25	7.29	6.99	16.15	15.65	2.35	1.85	0.355	0.305	General
M10 x 1.50	9.25	8.95	20.05	19.55	2.78	2.02	0.418	0.342	General
M10 x 1.50	9.25	8.95	20.05	19.55	2.78	2.02	0.418	0.342	Appearance
M12 x 1.75	10.95	10.65	21.65	21.15	2.98	2.22	0.418	0.342	General
M14 x 1.5	13.25	12.75	25.12	24.86	3.50	3.00	0.430	0.380	General

Body – Appendix III – Design Principles To Eliminate Squeaks & Rattles – General Principles



SQUEAKS & RATTLES

Squeaks and Rattles are ***Unwanted Sounds*** that are annoying, irritating, and/or disturbing — sounds without agreeable quality. Some examples of causes are:

HITTING

SLIDING
SLIP-STICK CONDITION

VIBRATING

To prevent unwanted sounds follow one or more of the

"KISS"

principles for all operating positions and conditions.

Klearance

Parts must ***never*** touch under variations in the following conditions:

Environmental – Temperature, humidity

Operating – Severe road inputs, various engine operating conditions

Manufacturing – Process variation, manufacturing tolerance

Isolate

Close or touching parts must be separated with isolation materials.

Examples are: Foams, felts, sleeves, rubber bumpers, heat shrink tubing, nylon, spacers, tapes (cloth, urethane, mylar), weld through sealers, lubricants, coatings, flocking, etc.

Structure

Parts and systems must be designed with adequate stiffness and strength to hold their own shape and avoid resonant vibration.

Examples are: Cross car beams, ribbing, material thickness, material selection, composites, gussets, I-beams, channel sections, box sections, etc.

Secure

Parts must be fastened to prevent relative motion.

Examples are: Welds, heat stakes, clips, rivets, bolts, tapes, adhesives, crush ribs, spring locks, etc.

Squeaks and rattles (S&R) are unwanted sounds that are without agreeable quality. Some examples of causes are: hitting, sliding (slip-stick condition), vibrating.

To prevent unwanted sounds follow one or more of the four principles below for all operating positions and conditions.

Klearance - Parts must never touch under variations in the following conditions: environmental - temperature, humidity operating -severe road inputs, various engine operating conditions manufacturing - process variation, manufacturing tolerance

Isolate - Close or touching parts must be separated with isolation materials.
Examples include foams, felts, sleeves, rubber bumpers, heat shrink tubing, nylon spacers, tapes (cloth, urethane, mylar), weld through sealers, lubricants, coatings, flocking.

Structure - Parts and systems must be designed with adequate stiffness, strength, and damping to hold their own shape and avoid resonant vibration.
Examples are cross-car beams, ribbing, material thickness, material selection, composites, gussets, I-beams, channel sections, box sections.

Secure - Parts must be fastened to prevent relative motion.
Examples are welds, heat stakes, clips, rivets, bolts, tapes, adhesives, crush ribs, spring locks.

Body – Appendix III – Design Principles To Eliminate Squeaks & Rattles – Instrument Panel

Klearance (Clearance)

1. There shall be a minimum of 1.5mm design clearance between the cluster trim plate and the gauge cluster assembly. Isolation is required to maintain this clearance; rubber tipped standoffs is one method (reference "Isolation" item #3 below).

2. There shall be a minimum of 5mm design clearance between the cluster trim plate and the steering column or isolation is required. These clearances are to be maintained for all positions of the steering column.

3. There shall be clearance for keys in the key cylinder to allow for a 140mm long keyring/fob assembly swinging from the key cylinder with the column in all positions, or isolation is required.

4. There shall be 5mm minimum design gap between the trim plate and the side door trim.

5. For flush fit style□trim plates, there shall be 0.5mm minimum design clearance between the trim plate and the perimeter of the radio/HVAC control head. It is recommended to attach the trim plate to the radio head and HVAC control head to minimize the affect of variation, minimize relative motion, and maintain the clearance.

6. A minimum of 0.5mm design clearance shall be maintained between the trim plate and it"s adjacent, non-overlapping I/P mounted trim panel (e.g.: knee bolster, accessory power point/outlet door, top pad/close-out, etc). A minimum 3mm wide surface should be placed at the interface of the two panels to allow application of isolation material if it is found to be needed.

Isolation

1. To prevent material itch/wear at trim to carrier substrate and trim to trim interfaces, the use ofolefin based plastics (e.g. polypropylene, unpainted TPO or polyethylene) for trim plate substrate materials is recommended. This is particularly important with chromed trim pieces on the trim plate. When using all other material types in combination with styrenic (e.g. ABS,PC+ABS, dylark, etc) or painted I/P carriers , isolation is required (e.g.: using rubber tipped clip standoffs, felt along edges, UHMW tape, paint masking, etc) at trim to trim and trim to carrier substrate contact points, including locators. ABS and PC/ABS is not recommended. Isolation has been found to be operator sensitive and prohibitively costly, proper choice of materials is a much more economical and robust.

2. For soft surface I/P carriers, the use of unpainted TPO or O"Sullivan WR-P4NAST "soft feel" vinyl skin is recommended if trim plates are designed with no clearance to the carrier skin. If unpainted TPO or O"Sullivan WR-P4NAST "soft feel" skin is not used, or the trim plates are not made of polypropylene or unpainted TPO, then isolation is required. An aggressive or heavy type grain applied to the trim at the interface to the soft surface of the I/P carrier can sometimes be used in place of an isolation material. It is recommended to always leave a flat surface at the perimeter of the trim plate backside to allow application of isolators if isolators are found to be needed.

3. For picture frame style trim plates, the use of rubber isolators between the trim plate and components (e.g.: cluster assembly, radio, HVAC control head, headlamp switch, etc.) is required. A minimum of 6 rubber isolators is required. The maximum distance between isolators shall not exceed 150mm and are required around the entire perimeter of the trim plate opening. Ideally, the standoffs should intersect the adjoining component at a 90 degree angle. The standoffs onto which the rubber isolators mount shall have flat tips with an area exceeding 4 square millimeters to prevent the trim plate standoff from wearing through the rubber tip isolators.

4. For chrome plated trim pieces located on the I/P trim plate, prevent or minimize chrome plating in the hidden portions of the trim to reduce the chance of material itch noises. This includes the attachments and locators for the chrome trim pieces.

Body – Appendix III – Design Principles To Eliminate Squeaks & Rattles – Instrument Panel, cont.

Structure

1. Stiffening ribs on the backside of the trim panels are recommended to maintain the trim panel design intent shape and clearances after trim installation. This can also be achieved by crowning the trim plate during molding process.

Secure

1. Option delete plates shall be secured in all six degrees of freedom using preloaded attachments (e.g.: crush ribs, retainers with angled back cuts, etc.) to prevent relative motion between the option delete plate and the trim plate.

2. Switches attached to I/P trim plates shall utilize preloaded attachments (e.g.: rubber bumpers, preloaded snap fits, etc.) to prevent relative motion between the switch and the trim plate.

3. When using clips, screws are recommended in hidden areas, such as along the bottom edge of the trim plate, to minimize relative motion between the trim plate and carrier. Do not thread screws directly into plastic bosses. For trim plates not made of unpainted olefin plastics (e.g. polypropylene or TPO), avoid using post style, non-attaching locators. These locators itch against the I/P carrier resulting in the need for isolators. Avoid cantilevered sections of trim secured by butting into an adjacent portion of the I/P. Avoid bayonet style clip attachments.

4. 4.2 diameter trim screw fasteners shall have a minimum dynamic torque specification of D2.5 Nm +/-0.5Nm, S1Nm Min when driven into metal nut members. Where screws are used, incorporate multi-threaded barrel expansion nuts. Screws with flat washer assemblies should be used when mating to plastic to distribute bearing surface clamping forces and prevent deformation or cracking of the mating plastic. Fastening directly into plastic is not preferred. Do not use sheet metal tapping screw thread profiles into plastic bosses, use only thread forming screws for plastics.

5. For vehicles designed for truck usage schedules, the use of a minimum of four screws, combined with U-base self locating clips to fasten the cluster trim plate to the I/P carrier is recommended. It is recommended that all other trim plates utilize a minimum of one screw attachment.

6. For trim plates utilizing screw attachments, place the non-retaining post style locators as close as possible to the screw attachment points to prevent them from itching against the I/P carrier. This helps prevent the need for isolators. Minimize the number of these locators. For locators made of polypropylene and unpainted TPO, utilize crush ribs on the locator for an interference fit to the mating part to avoid buzzing noises at the interface. Also, locators shall extend beyond the attachment so that the locators engage the I/P first.

7. Fastener spacing of 150mm maximum is recommended.

8. When installing chrome trim on I/P trim plates, locators should also function as attaching points to avoid locator to trim plate noise. Also, for I/P trim plates not made of polypropylene or unpainted TPO, any chromed trim pieces attached to the I/P trim plate shall be attached with glue or two sided adhesive tape. The glue and tape prevent relative motion between the I/P trim plate and the chrome trim. Make sure the surface on which the glue will be adhering has some profile (not smooth) to allow the glue to stay adhered. If glue cannot be utilized, isolation is required.

9. Items secured to the trim plates shall be attached using methods that will prevent relative motion between the attachments and trim plates or isolation is required.

10. Storage pocket rubber inserts shall be secured to the trim plate to prevent rattles due to relative motion between the two.

Body – Appendix III – Electrical

Klearance (Clearance)

1. Determine wiring harness bundle size, path, and breakouts. This will ensure that adequate "real estate" is provided to accommodate the wiring harness.
2. Route the wiring harness as straight as possible minimizing bends, twists, etc.
3. Provide clearance for wiring and connectors between moving door parts and glass (all positions).
4. For specific applications, fasteners can provide clearance.
5. The direction and location of breakouts is critical. Minimize the distance between breakout location and component to 150mm. If the breakout exceeds 150mm, additional pre-loaded attachments are required.

Isolation

1. Service loops must be isolated and/or secured. If the service loop splits into multiple branches, each branch needs to be isolated.
2. The recommended wiring cover material in the I/P, console, side doors, headliner, package shelf and seats is cloth tape (0.80 mm thick stitch-bonded PET non-woven tape). The recommendation at all other interior locations is 0.27-mm thick woven polyester cloth tape.
3. If possible, keep the length of service loops to a maximum of 150mm. For all service loops the wiring shall be tape wrapped the entire length.

Structure

1. To maintain the wiring harness position, the mounting surface must ensure three-dimensional integrity. Additional parts are needed for dimensional integrity at transitions-(e.g., molded plastic guides, channels or possible steel rod inserts).

Secure

1. The wiring harness must be securely retained in position with pre-loaded single-position clips. Maximum spacing of attachments is 150 mm in the interior (including the door inner and liftgate) and 200 mm under hood, underbody, or any interior (non-door) harness wrapped with 0.80 mm thick stitch-bonded PET non-woven tape. When the harness changes direction, attachments are required as close as possible to the transition.
2. The design must ensure operator visibility of attachments and specify breakout positions and directions.
3. Plastic convoluted conduit has a propensity to rattle. It should be avoided whenever possible. If conduit must be used recognize that:
A) Wiring can rattle within the conduit. Choose the proper size to prevent wiring from moving or provide some type of filler material (e.g., foam).
B) Conduit can rub or vibrate against a harder surface or itself. It must be secured every 150 mm (more often when changing directions) unless secured by other means (e.g. carpet, etc.). Isolation or clearance must be provided at any remaining contact points.
4. The edge over metal clip is not recommended.
5. The characteristics of preferred attachments are positive retention feedback to the operator, have insertion forces meeting ergonomic requirements and a pre-load mechanism to avoid rattles in the inserted position. Some fasteners are sensitive to panel thickness therefore the length of the fastener must vary dependent upon the panel surface. The fastener must be serviceable to avoid removal damage.

Body – Appendix III – Electrical, cont.

6. The "fir tree" or "christmas tree" fastener can be used on the chassis, powertrain and under carpet inside the vehicle. When used, the fastener must meet ergonomic insertion force requirements which will help to ensure engagement of the preload feature.

7. Avoid using attachments without preload mechanisms.

8. Adjustable fasteners should be sized appropriately for the diameter of the wiring bundle. Tie straps are not recommended for small bundles. If a tie strap is used, the tail must be cut off. When a tie strap is not used, a fastener that preloads the wire bundle must be selected. Whenever possible, a female connector should be part of component assembly.

10. If the mating connector cannot be part of the assembly, then it must be securely retained to a structural part.

11. Unused connectors must be positively located. Use a dummy connector or tape the unused connector to the harness.

12. "Zero" clearance between connector mates is required to prevent rattles. Crush ribs, spring locks, etc. are means to achieve "Zero" clearance.

13. Terminal Position Assurance (TPA) and/or Connector Position Assurance (CPA) fasteners must be free of movement when engaged regardless of the number of unused cavities.

14. Do not use adhesive tape or "two sided sticky-tape" to secure wire harnesses. Adhesive tapes tend to lose strength at extreme temperatures.

15. Connectors must be adequately secured with pre-loaded attachments, or be isolated as required, to prevent rocking and any contact with the substrate.

Body – Appendix III – Interior Trim

- Locator tab must be short and strong so they will not break off during assembly.
- Look out for molding rattle against weld flange, body panels or against each other.
- Large trim panel requires more locator tabs and securing points for securing because of low stiffness. Or else, use foam insulation to preload panel.
- Trim should be separated by space (at least 2.5mm) or by fasteners.
- Overlapping trim piece should use foam or fastener for insulation.
- All convenience equipment (such as ash trays, storage bucket, etc.) should be attached and secured from rattling.
- Utilize stand-off ribs to create pre-load or clearance between surfaces.
- Vinyl and leather trim should not rub against other components.
- Pre-load trim around manual window crank to prevent rattling of crank.
- All trim pieces should have good clearance from door trims and window glass (at least 5mm).
- Clearance of A-pillar molding to windshield should be 5mm.
- Headliner must be secured and have sufficient gap (5mm) from windshield to prevent itching, vibration, and rattling.
- Fasteners must be stronger than the thread to prevent threading.
- Provide preload to interfacing parts to prevent potential vibrations.
- Support for speaker attachment must be rigid.
- Use foam to separate surfaces that are in close proximity.
- Speaker grill and the attachment area must be rigid to accommodate for more powerful and heavy speakers.
- Trim plates should have tight tolerances to ensure clearance or interface fit.
- Provide insulating material (foam or anti-itch tape) between surfaces in proximity from rattling or vibration.
- Avoid plastic bosses in the injection molded panel and trim plate in structural application since the plastic will creep under load.
- When two vinyl or plastic panels are requried to be attached together – a concealed joint line should be designed.
- Snap-in assembly should only be used for components that are not frequently removed in order to preserve the designed tightness.
- Increase trim's tapered corner (for decreased rib length) to prevent squeak or itch.
- Trim should not fucntion as direct loading support.
- Attachment fastener should be in a tension state with the attaching surface.
- Trim that are designed to preload against each other may lose its tension because of temperature cycling.
- Design with common parts, common method and specification for assembly.
- Beware of trim's rib locations relative to parts in near proximity.
- Locate retractor behind trim (with good separation) and away from the ears location if possible for better sound insulation.

Body – Appendix III – Body & Exterior Trim

- Reduce or avoid metal maintenance access panel because of the possible loss, loose or missing screws during assembly.
- Component should not be mounted in the center of large panels that have low structural stiffness.
- Component should be mounted to flanges, at corners, ribs or beads – but need to consider fatigue from stress concentration and component contact.
- Utilize foam as an insulator or a spacer in hollow space to prevent oil canning sound.
- Instead of snap fit to join two plastic parts, consider machine screw fastener with U-nut or snap-in for better retention.
- Most of rattling can be eliminated if the vehicle body or the mounting bracket is stiff against bending and twisting.
- Avoid multiple and overlapping trim pieces due to itch and difficult alignment.
- Window moldings and external trims must be made of materials that will not itch when rubbed against body surfaces (check by rubbing sample against painted panel).

Body – Appendix III – Seats

Klearance (Clearance)

1. Maintain minimum clearance of 15 mm between console and all parts of seat (seat cushion, seat back, armrest, track, and track cover) to avoid squeaks and itches in all seat positions, including 95th percentile occupant. If clearance cannot be maintained, isolation is required.

2. Maintain minimum clearance of 10 mm between trim panels and all parts of seat (seat cushion, seat back, armrest, track and track cover) to avoid squeaks and itches in all seat positions, including 95th percentile occupant. If clearance cannot be maintained, isolation is required.

3. Maintain minimum clearance of 20 mm between door trim panels and all parts of seat (seat cushion, seat back, armrest, track and track cover) to avoid squeaks and itches in all seat positions, including 95th percentile occupant. If clearance cannot be maintained, isolation is required.

4. For vinyl or leather seats, maintain clearance of 5mm between side track shields and seat cushion in all seat positions during all static and dynamic conditions, including 95th percentile occupant. If clearance cannot be maintained, isolation is required.

5. Except at attaching points, sidetrack shields shall maintain 5mm of clearance to seat base tracks and any attaching components. If clearance cannot be maintained, isolation is required.

6. If an under seat storage bin is used, a preloading fit shall be designed into the track interfaces. This will minimize rattles within the track system. In addition, to reduce track wear, the track system should incorporate a self-lubricating material and/or utilize a bearing type system.

7. All levers and related components in the adjuster mechanism shall have a minimum of 10mm clearance to floor and other components (including side track shields). Electric motors must also maintain a 10 mm clearance to prevent grounding out against adjacent components.

8. All seat trim fasteners (head & tip) must have a minimum of 5 mm clearance to its surrounding interface areas including full seat travel of the seat mechanism (Up / Down, Fore / Aft) to prevent squeaks & rattles.

9. Design Clearances between the upper and the lower channels of the seat tracks are very critical and necessary to achieve a low sliding effort and not create chucking / rattles.

10. Except at attaching points, provide a minimum of 5mm clearance between structural brackets to avoid metal to metal creaks. All points of contact should be attachments.

Isolation (I)

1. Use isolation at sides of vinyl or leather seat cushion to prevent squeaks and itches against adjacent surfaces.

2. Use isolation at interface of vinyl or leather armrest to seat back to prevent squeaks and itches.

3. Use isolation at interface of vinyl or leather seat back to seat cushion to prevent squeaks and itches.

4. If an under seat storage bin is used, it is recommended to line with a soft, compliant material along the bottom and sides to minimize rattle noises between the container and its contents.

5. It is recommended to use polypropylene, TPO, or polyethylene on any plastic seat belt escutcheon that is attached over or next to vinyl or leather seats to prevent itches. If these materials are not used, isolation will be required.

6. If preloading interfacing parts is not possible, it is recommended using a plastic or rubber coating on all metal linkages and attachment points in the seat recliner mechanism to prevent rattles.

7. Isolation is required at interface of vinyl or leather headrest to seat back to prevent itches

Body – Appendix III – Seats, cont.

8. To reduce seat back chucking, nonmetallic bushings and washers are recommended at the main recliner pivot point.

9. Seat track shields that interface the vinyl or leather seat cushions shall to be made of Polypropylene, unpainted TPO, or polyethylene, or isolation is required at the interface.

10. Seat cushion support mat wires must be plastic coated at the interface to the seat frame to prevent squeaks.

11. Seat back recliner coil spring ends must have lubrication at the interface to the seat structure to prevent squeaking.

Structure (St)

1. Use ribbing on inside of plastic sidetrack shields to help maintain their structural integrity under all thermal conditions to avoid contact with other parts and prevent squeaks & rattles.

2. Headrest post(s) and guides shall be designed with sufficient rigidity so that no relative movement is allowed between secured items to prevent rattles.

3. Ensure surface contact between seat attachments and the mounting surfaces. Point or partial contact must be avoided.

4. Ensure that the seat attachment to the floor is as close to the vertical portion of the seat leg as possible to increase seat stability and avoid seat foot rattles to the floor. Also, minimize leg cantilevered bends which decrease seat structural rigidity. Consider adding stiffening ribs and/or darts at the corners to maximize structural rigidity.

Secure (Se)

1. Seat wiring harness connectors and wiring shall be secured every 150mm with preloaded attachments to prevent connector and wires from rattling against floor or seat assembly.

2. Seat mechanism cables shall be properly secured every 200 mm to prevent from rattling against seat and surrounding components or isolation will be required.

3. All mechanical linkages shall be preloaded, in their natural design state, (e.g. Recliner handle, recliner shaft) or isolation will be required to prevent squeaks and rattles.

4. Staked hinge pin pivots are not recommended. Shoulder bolts are recommended to minimize tolerance variation and prevent pivot looseness.

5. Articulating headrest post(s) shall have an interference fit to the seat attachment or be pre-loaded to prevent loose headrests and consequent rattles.

6. All seat tracks shall be preloaded to prevent chucking / rattles.

7. If a seat belt assembly is attached to the seat, ensure surface contact between the seat belt anchor assembly and the seat mounting surface. Point or partial contact shall be avoided. Multiple attachments are strongly recommended and cantilevered supports shall be avoided.

8. Positive attachments are recommended to mount seat belt anchor plates.

9. Seat cushion material located between the structure and seat fabric must be secured to the structure with attachments that prevent relative motion, or isolation is required.

10. Fasteners attaching seat components to metal or other hard portions of the seat must be preloaded to prevent relative motion.

Body – Appendix III – Seats Belts

Klearance (Clearance)

1. The buckle shall be designed to angle away from the console and provide a minimum of 15mm clearance between the buckle assembly, in its free state, and the console. If this is not obtainable, the sleeve may be enlarged to provide an interference fit, given the materials are compatible, or isolation will be required. This is to prevent the buckle assembly from rattling against the console.
2. Adjacent buckles shall have clearance to each other in all service conditions or be secured together. If clearance of adjoining buckles is not obtainable, isolation is required.
3. A webbing button or sewn flap is recommended to position the latch plate assembly and provide clearance to unfriendly surfaces when in the stowed position.
4. Guide loop bushings are recommended to locate the guide away from the trim.

Isolation (I)

1. Isolation shall be required when any part of the seat belt buckle assembly can contact vinyl or leather seat trim. This may not be necessary if an anti-squeak top coating is applied to the seat side facing or if compatible materials are used.
2. Isolation shall be required when any part of the seat belt latch plate assembly will contact unfriendly or incompatible surfaces.
3. The use of Polypropylene for seat belt buckles and covers has proven to be a robust design in the prevention of squeak and itch noises between the buckle and the seat covering.

Structure (ST)

1. A stiffener may be used to reduce buckle assembly motion or to increase the resonant frequency to eliminate rattles.

Secure (SE)

1. Free play shall be minimized when using shoulder bolt attachments. Isolation is requiredif free play still allows rattles.
2. A retention strap may be used to help hold the buckle assembly to the seat to reduce lateral motion. Cloth straps (or equivalent) are recommended.
3. Ensure full contact for components that have one attachment point. Robust anti-rotation provisions are recommended (i.e. preloaded tab) to prevent unwanted rotation and cause possible squeaks and rattles. Point or partial contact must be avoided.
4. In the latched position, the seat belt buckle shall provide sufficient preload on the latch plate tongue to prevent rattles.
5. The seat belt buckle release button preload shall be sufficient to prevent rattles in both the latched and unlatched conditions.
6. Sufficient belt tension is recommended to minimize latch plate assembly free swing and rattles when in the stowed position.
7. Seat belt buckle wiring harnesses must be securely retained in position with pre-loaded clips.
8. Seat belt buckle sleeves must be securely attached to the belt assembly to prevent rattles.
9. In order to prevent rattles, it is recommended that all seat belt labels be heat applied or label sewn to belt so that label does not have a loose end.

Index

EXTENDING WHEELBASE/MOVING AXLE **1**
- Frame Extension 1
  - Alterations 1
  - Frame 1
- Altering the Wheelbase 2
  - Frame Splice Location 2
  - Frame Splice Preparation 3
  - Frame Splice Procedure 4
- Extending the Frame (Rear Overhang) 7
- Holes 8
- Crossmembers 9
- Analyzing Frame Failure Causes 10
  - Collisions 10
  - Excessive Bending Moment 10
  - Localized Stress Concentration 10
  - Attaching Reinforcements 11
  - Terminating Reinforcements 12
- Welding 12
  - Welding Equipment 13
  - Welding Methods 14
  - Dissimilar Metals 14
- Driveshaft (Propshaft) Extension 16
  - Driveshaft Extension Design 16
  - Two-Piece Driveshaft Bearings 17
  - Universal Joint Angles and Phasing 18
  - Multiple-Piece Driveshaft Alignment Procedure 19

Index (cont'd)

OCCUPANT BODY MOUNTING **20**
- General Requirements 20
- Body Mounting Considerations 21
- Body/Equipment Attachment Methods 21
  - Body Mounting Fasteners 22
  - Prevailing Torque Nuts (PTN) 23
- NTEA Recommended Body-Mounting Practices 23
  - Type 1 – U-Bolt/Threaded Rod and End Plate 23
  - Type 2 – Brackets and Pinch Bolts 23
  - Type 3 – Rigid Mounting (Service/Utility) 23
  - Type 4 – Shear Plate Mounted 23
  - NTEA Body Classifications 24
- Shear Plate Attachments 27

FUEL SYSTEMS **28**
- Fuel Fill 28
- Fuel Lines 29
- Fuel Tanks 30
  - Auxiliary Fuel Tanks 31
- Diesel Exhaust Fluid (DEF) System 31

BRAKES **32**

General Requirements 32

Federal Standards and Regulations 32
- Modification Checklist 32
- Brake Lines 33

Parking Brake Systems 34

Electronic Dynamic Rear Proportioning (DRP) 35

Index (cont'd)

EXHAUST SYSTEM **36**
Exhaust System Design 36
    Routing 38
    Shielding 38
    Undercoating 38

SUSPENSION SYSTEM **39**
  General Requirements 39
  Front Suspension 39
  Rear Suspension 39

WHEELS AND TIRES **40**

Extending Wheelbase/Moving Axle

Frame Extension

The frame extension is designed to maintain structural rigidity and performance while minimizing cost and part/assembly complexity. General Motors has conducted extensive engineering analysis of the frame with the objective of replicating base frame thickness for optimum dynamic performance. This analysis is the basis for recommendations on frame construction sections, section modules, metal thickness and specifications.

The frame extension must overlap the existing frame to ensure adequate strength in the tie-in areas. These areas are vehicle stress risers, subject to significant loads even during normal vehicle use. SVMs, therefore, should make every attempt to ensure consistent installation in the tie-in areas.

Alterations

When modifying the wheelbase, SVMs assume full responsibility for:

- compliance with applicable motor vehicle safety standards
- warranty on items such as driveshafts, universal joints, center bearings and rear transmission tailshaft, transfer case and transmission case fractures, output shaft bushings, bearings, brakes, fuel systems and any other related component failures.

Additionally, the modifier's owner manual must alert the customer that parts for the reworked area(s) are not available through the General Motors service parts system.

Frame

The SVM is responsible for any alterations to the frame assembly, including hole drilling, welding and modifications of any type.
The SVM must also assume complete responsibility for reliability, performance and compliance to applicable FMVSS requirements.

This section outlines GM-recommended procedures and precautions for proper installation of special bodies and/or equipment on frames. Failure to follow these recommendations could result in serious damage to the basic vehicle.

Flanges

GM does not recommend drilling holes in frame flanges. Drilled holes in frame flanges will reduce fatigue life significantly. See Figure 10, page 9.

Holes

When drilling holes for mount brackets, supports and outriggers in the frame rail vertical side wall, SVMs should observe the following recommendations:

- Material between the edge of the hole and inside of upper or lower flange must not be less than 37 mm (1.5 in.).
- The minimum edge distance between any two holes must be larger than twice the diameter of the larger hole.
- No hole should exceed 20 mm (0.75 in.) in diameter.

Extending Wheelbase/Moving Axle (cont'd)

Altering The Wheelbase – Frame Splice Location

General Motors recommends splicing in a straight segment of the frame rail, just forward of the rear spring front hanger bracket (see Figure 1). This is the optimum location for maintaining frame strength and integrity. It also maintains minimum weld spacing from hanger bracket rivet, preventing hole/rivet shrinkage deformation. Other advantages to this location are:

- Requires minimal exhaust, fuel, brake and electrical modifications.
- Minimizes driveline modification issues from excessive angles and misalignment.

CAUTION Avoid altering chassis wiring. When shortening the wheelbase, simply secure a gentle bend or loose coil in the wiring.

CAUTION Avoid cutting on uneven sections of the frame, such as frame forms or irregular bends and depressions.

CAUTION General Motors highly recommends selecting a cut location approximately 203 mm (8 in.) forward of the rear spring front hanger bracket whenever possible. If using another location with the splice zone, SVMs should complete a stress analysis.

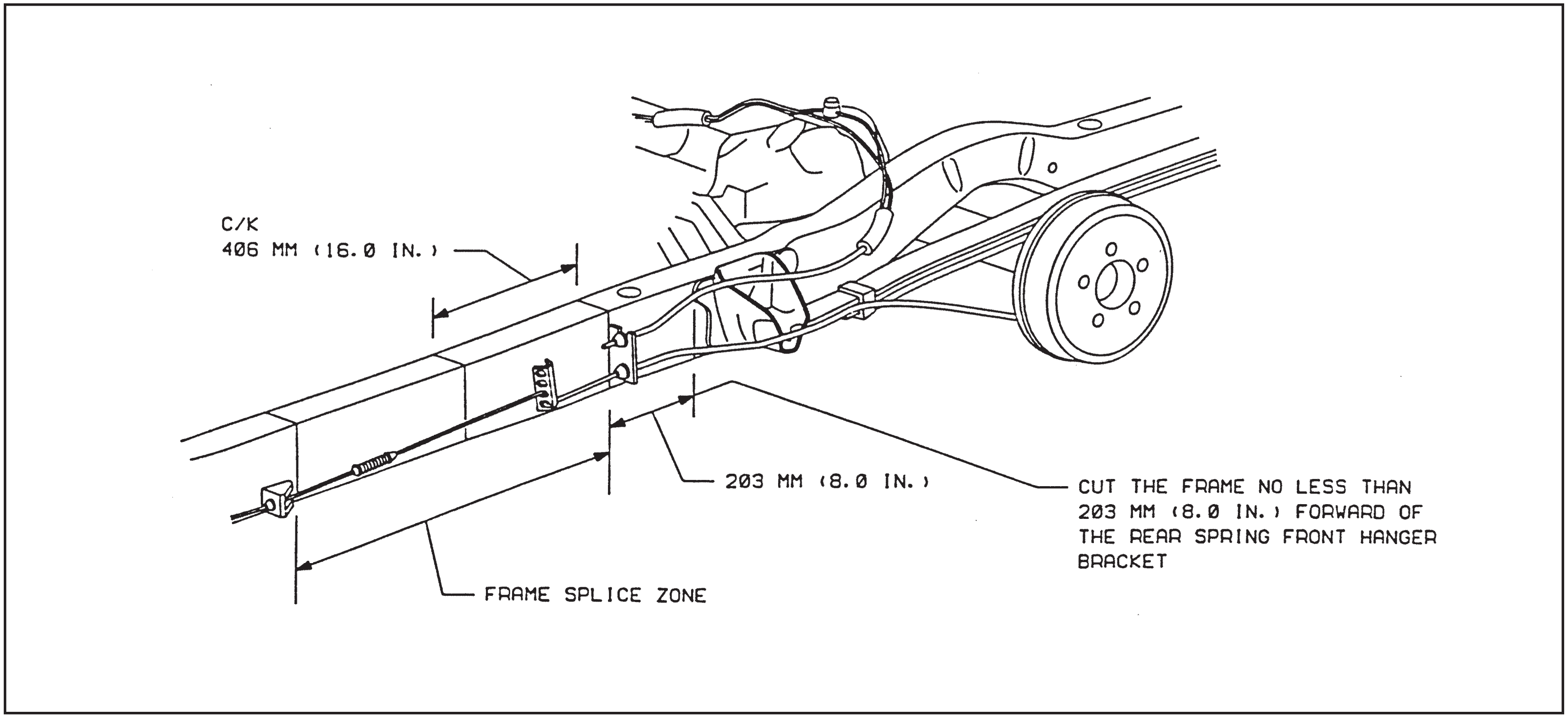

C/K
406 MM (16.0 IN.)
203 MM (8.0 IN.)
CUT THE FRAME NO LESS THAN 203 MM (8.0 IN.) FORWARD OF THE REAR SPRING FRONT HANGER BRACKET
FRAME SPLICE ZONE

Figure 1

Extending Wheelbase/Moving Axle (cont'd)

Frame Splice Preparation

The following steps are recommended as preparations for altering the wheelbase:

1. Disconnect the battery (negative cable first), if not already done.
2. All OEM frames are dipped in wax for improved corrosion protection. Before beginning any welding operation, locally remove the wax using one of the following methods:
   - Steam
   - Hot water at approximately 500 PSI
   - Scrape and then use mineral spirits to wipe off any remaining wax.
3. Choose a cutting location that will be able to withstand any outer reinforcements that will be added in later operations. The reinforcement should extend beyond either end of the frame insert by a minimum of 152 mm (6 in.).
4. Scribe or mark the frame for cutting (Figure 2). Record all dimensions for gauging or fixturing on the Frame Splice Process Check-List.
5. Attach a cutting fixture/rest to the frame for increased cutting accuracy.
6. Medium Duty vehicle with I-beam front axles: Use the correct tie rod arms when significant shortening or lengthening is planned. Consult the General Motors Parts Catalog for the proper selection.

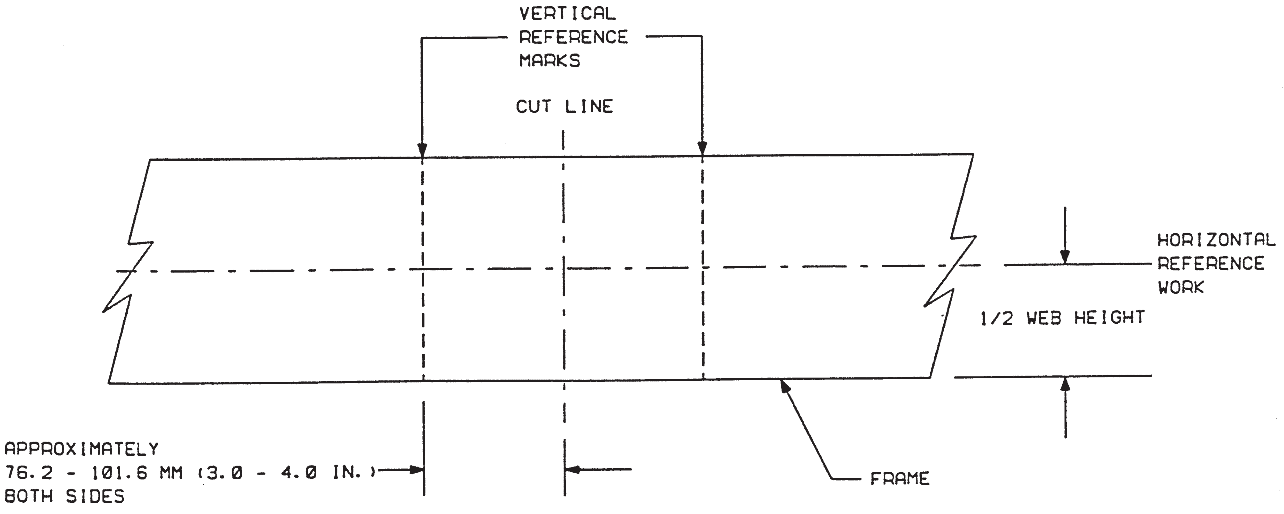

VERTICAL REFERENCE MARKS
CUT LINE
HORIZONTAL REFERENCE WORK
1/2 WEB HEIGHT
APPROXIMATELY 76.2 - 101.6 MM (3.0 - 4.0 IN.) BOTH SIDES
FRAME

Figure 2

Extending Wheelbase/Moving Axle (cont'd)

Frame Splice Procedure

Use the following procedure for splicing the frame:

1. Locate a specific frame splice cut location, observing the location guidelines already outlined. Cut the frame within the frame splice zone.
2. Grind cut edges of the frame smooth for line-to-line fit. This ensures a good fit and clean metal surface for the welding operation.

! Frame inserts must be the same dimensional shape, metal gauge/thickness, material type and yield strength as the original frame side member.

3. Chamfer the outside edge of both the frame and the insert at a 30-degree angle, leaving 1/2 of the thickness (Figure 3).
4. Relocate rear frame section of the vehicle to install frame insert when lengthening.
5. Fixture and clamp the insert to ensure correct alignment (Figure 4). Make dimensional checks against predetermined reference marks (as shown earlier in Figure 2) to prevent possible error.

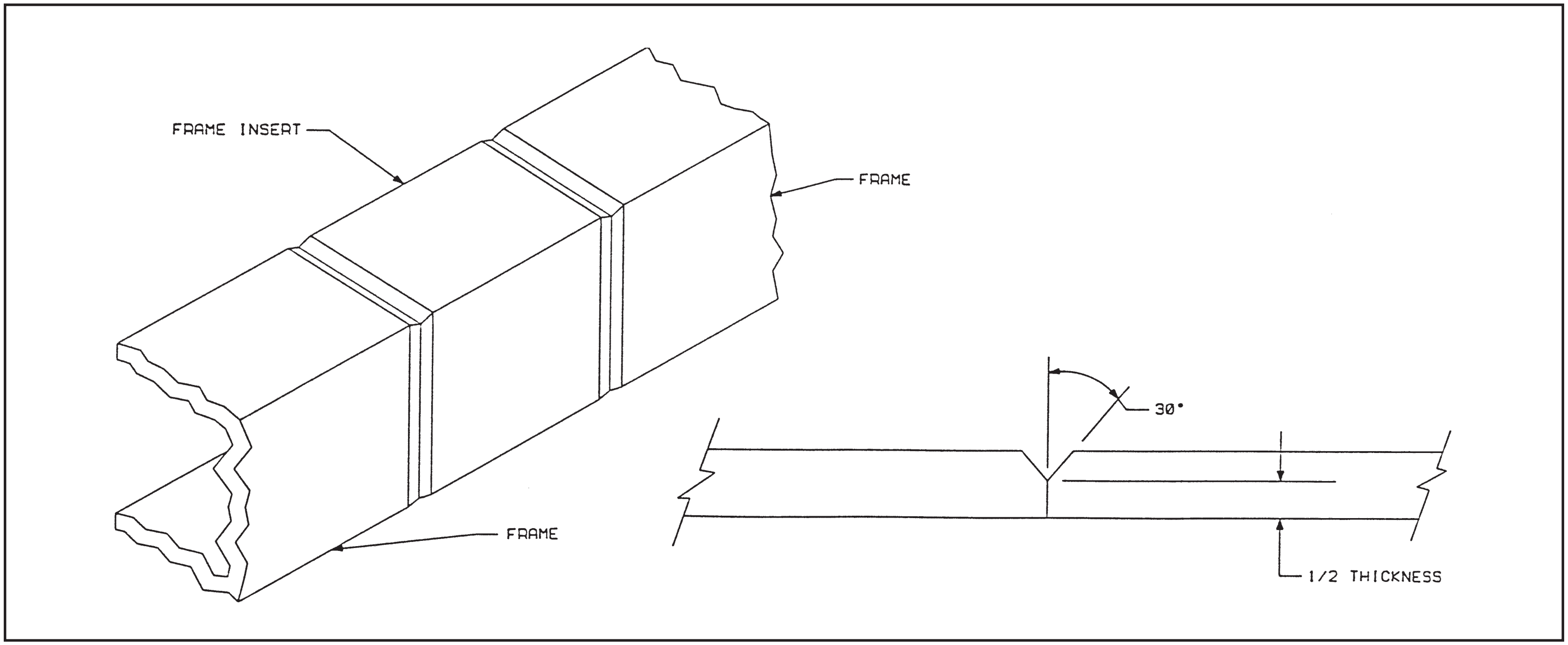


Figure 3

Extending Wheelbase/Moving Axle (cont'd)

6. Tack weld runoff blocks to the edge of the upper and lower flanges of the frame and frame insert (Figures 5 and 6). This helps to eliminate joint edge burnout and prevent joint movement during butt welding.

7. Butt weld the outside edges of the frame insert to the frame. Grind visible welds on both sides to parent metal.

8. Butt weld the outside of the joint with a single pass — vertical up (Figure 5). Butt welds on the inside surface of the frame should also be done with a single pass (Figure 6).

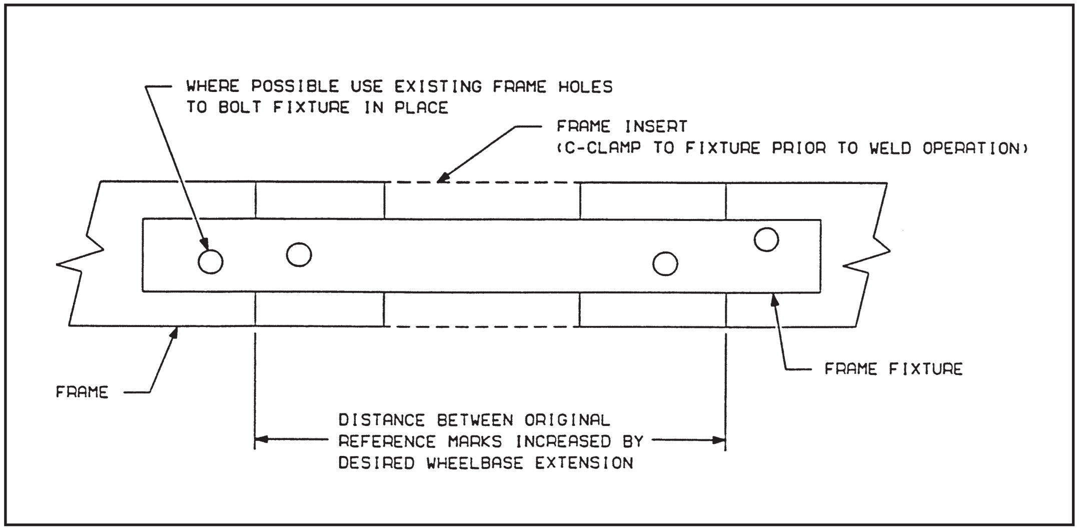

WHERE POSSIBLE USE EXISTING FRAME HOLES TO BOLT FIXTURE IN PLACE
FRAME INSERT (C-CLAMP TO FIXTURE PRIOR TO WELD OPERATION)
FRAME
FRAME FIXTURE
DISTANCE BETWEEN ORIGINAL REFERENCE MARKS INCREASED BY DESIRED WHEELBASE EXTENSION

Figure 4

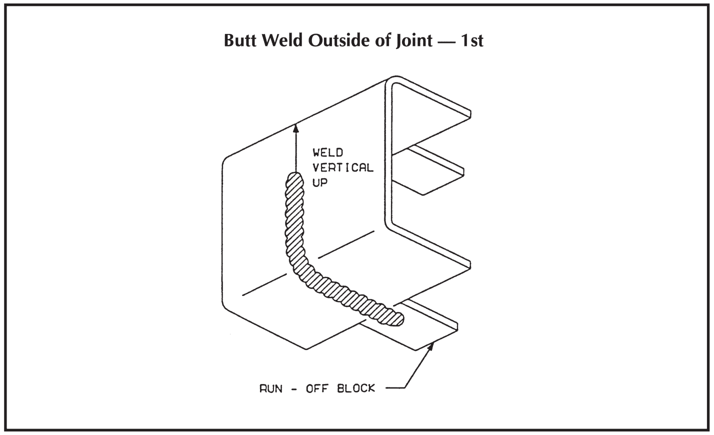

Butt Weld Outside of Joint — 1st
WELD VERTICAL UP
RUN - OFF BLOCK

Figure 5

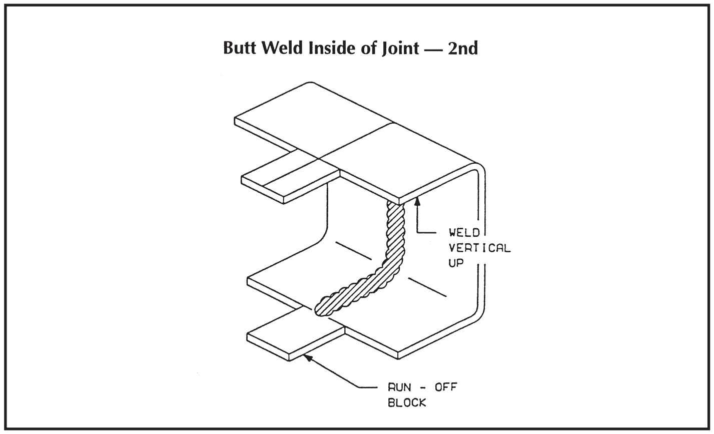

Butt Weld Inside of Joint — 2nd
WELD VERTICAL UP
RUN - OFF BLOCK

Figure 6

Extending Wheelbase/Moving Axle (cont'd)

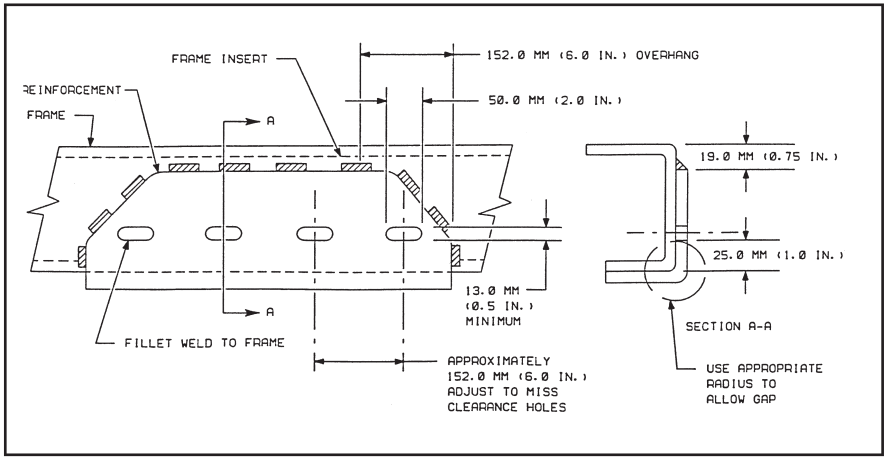

FRAME INSERT
REINFORCEMENT
FRAME
152.0 MM (6.0 IN.) OVERHANG
50.0 MM (2.0 IN.)
A
A
19.0 MM (0.75 IN.)
25.0 MM (1.0 IN.)
13.0 MM (0.5 IN.) MINIMUM
SECTION A-A
FILLET WELD TO FRAME
APPROXIMATELY 152.0 MM (6.0 IN.) ADJUST TO MISS CLEARANCE HOLES
USE APPROPRIATE RADIUS TO ALLOW GAP

Figure 7

! Variations in equipment and welding materials make it difficult to recommend specific amperage, electrode specifications and welding speed. Therefore, SVMs should have a qualified welder or consulting service establish and test this procedure. Standard industrial practices apply.

9. Visually inspect all welds for defects. This will ensure high-quality welds which are critical to joint integrity.
10. Remove runoff blocks and chip or grind the joint smooth. The outside surface of the frame weldment must be as smooth as the rest of the frame to allow flush fit for reinforcement attachment. Make sure that grind marks are parallel to the length of the frame. The finished joint should be of the same thickness as the sidemember.

! The outer reinforcement length is defined by the splice location and length of the insert, with a minimum 152 mm (6 in.) overlap on each end. The reinforcement must not encroach on the rear leaf spring front hanger bracket.

CAUTION Avoid welding closer than 50.8 mm (2 in.) to this area. Doing so could shrink the spring bracket rivets, resulting in a loose joint.

Refer to Figures 7 and 8 for clarification throughout this section. The illustration in Figure 7 shows an acceptable reinforcement and weldment method. The method shown in Figure 8, however, is preferred because:

- The slots are smaller and can be more easily positioned to avoid clearance holes in the frame.
- Chamfered sides diminish stress concentrations in corners which can cause cracks to develop in the weld.

Use an L-shaped reinforcement made of the same material and thickness as the frame. Reinforcement height must allow for the weldment, but not exceed the tangent of the radius for the bend at the upper flange of the frame.

The inside radius of the reinforcement must be smaller than the outside radius of the frame so as to provide a gap at the bend.

11. Add holes to the reinforcement to provide clearance for all fasteners, rivets or retention clips in the frame sidemember.

Any frame identification number or VIN which would be lost when the wheelbase is stretched or shortened must be duplicated on the reinforcement or sidemember of the finished frame.

Extending Wheelbase/Moving Axle (cont'd)

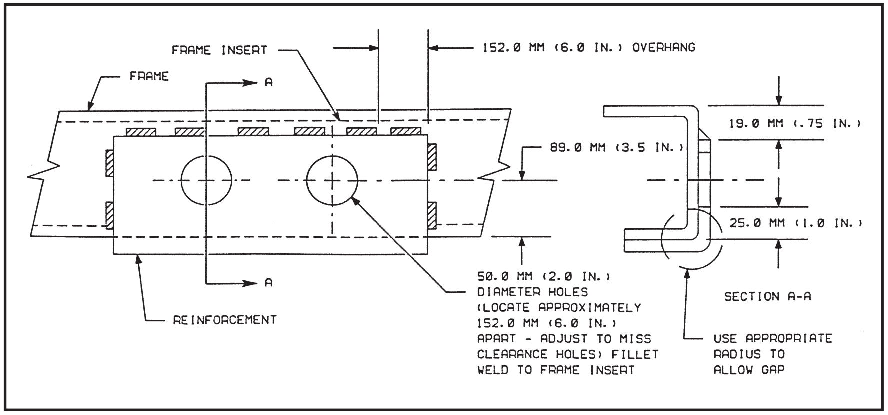

FRAME INSERT
152.0 MM (6.0 IN.) OVERHANG
FRAME
A
19.0 MM (.75 IN.)
89.0 MM (3.5 IN.)
25.0 MM (1.0 IN.)
A
50.0 MM (2.0 IN.)
DIAMETER HOLES
(LOCATE APPROXIMATELY
152.0 MM (6.0 IN.)
APART - ADJUST TO MISS
CLEARANCE HOLES) FILLET
WELD TO FRAME INSERT
SECTION A-A
REINFORCEMENT
USE APPROPRIATE
RADIUS TO
ALLOW GAP

Figure 8

Secure the L-shaped reinforcement with clamps to the outside of the frame rail. There should be no visible gaps between the frame rail and the reinforcement other than at the bend. Fillet weld the reinforcement to the frame rail, using a skip weld technique. That is, a 50.8 mm (2 in.) weld followed by an equal space continuously along the span of the reinforcement.

Leave corners, bends and radii free to flex. Welding in these locations creates stress risers that can often lead to cracks in the weld.

! Do not weld at the lower flange of the frame, either on the flange or at the edge.

! For the final weld operation, fillet weld the reinforcement slots or holes to the frame. It is acceptable, but not necessary, to fillet weld the entire circumference of the slots or holes. Adding a fillet weld on the bottom half (180 degrees) only will provide sufficient strength.

After final welding, reapply undercoating to the exposed portion of the frame unless the area to be covered is closer than 305 mm (12 in.) from any exhaust component. For components falling within this area, use paint rather than undercoating to provide corrosion protection.

Extending The Frame (Rear Overhang)

When lengthening rear frame extensions, SVMs must exercise great caution to avoid adversely affecting vehicle performance in the following areas:

- Excessive rear extensions allow customer opportunity to significantly unload the front end of the vehicle. This can result in customer dissatisfaction with vehicle braking and/or steering and handling.
- Rear frame extensions must be long enough to protect vulnerable components, such as fuel tanks, and short enough to avoid a negative effect on approach, departure and brake-over angles.

For guidelines on frame wax (corrosion protection) removal, refer to “Altering the Wheelbase” on page 3 in this section.

Extending Wheelbase/Moving Axle (cont'd)

Holes

It is important to locate holes in the least critical area possible. In high-load areas, place holes near the neutral axis of the side rail or horizontal center line of the web.

The illustration in Figure 9 was taken from a laboratory test conducted to study stress at a hole under beam loading. In this test, the section was covered with photo stress plastic which shows stress through color fringes when viewed under polarized light.

The illustration shows a channel-section siderail loaded vertically as a beam. This type of loading stretches the lower half of the section and compresses the top half as indicated by the arrows. There are two holes in the lower half, the uppermost of which is located about one-third of the rail depth up from the bottom flange. Stress at the bottom of this hole is approximately equal to the stress in the flange. Any hole located less than this distance from the bottom flange will have significantly higher stress than the flange. Figure 10 illustrates these principles more specifically.

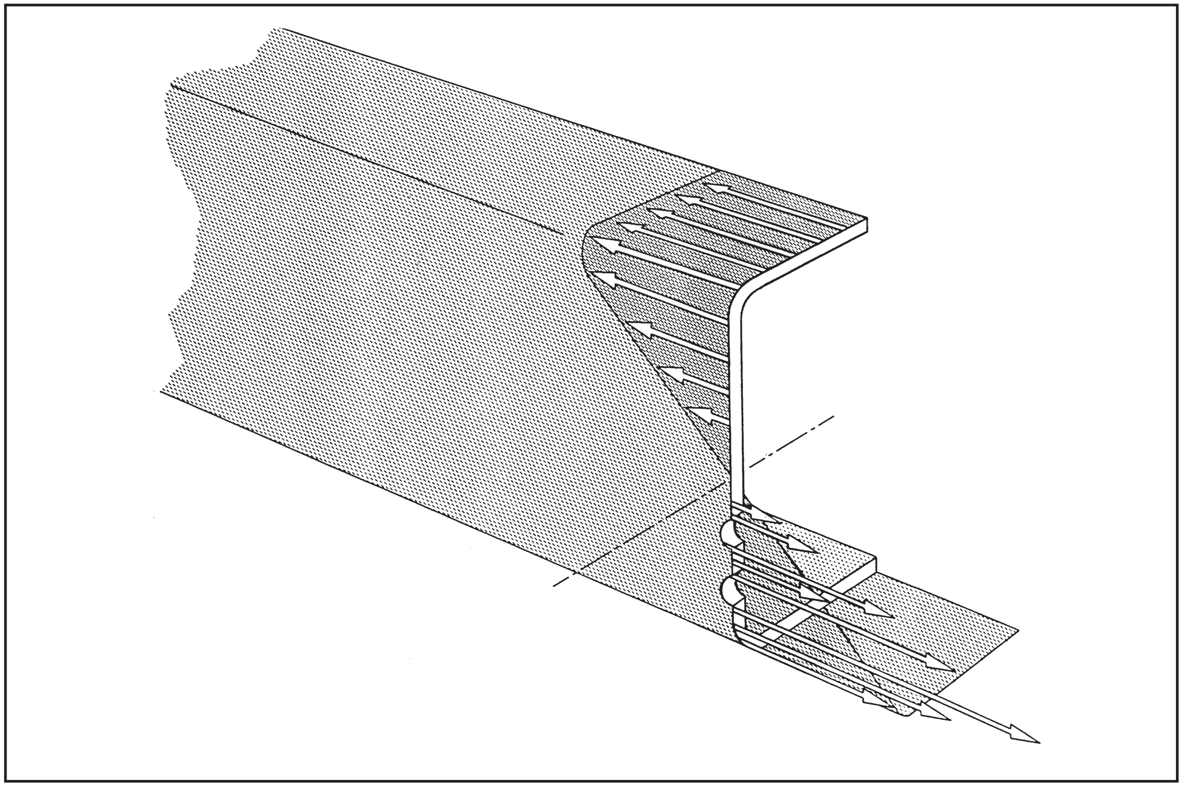
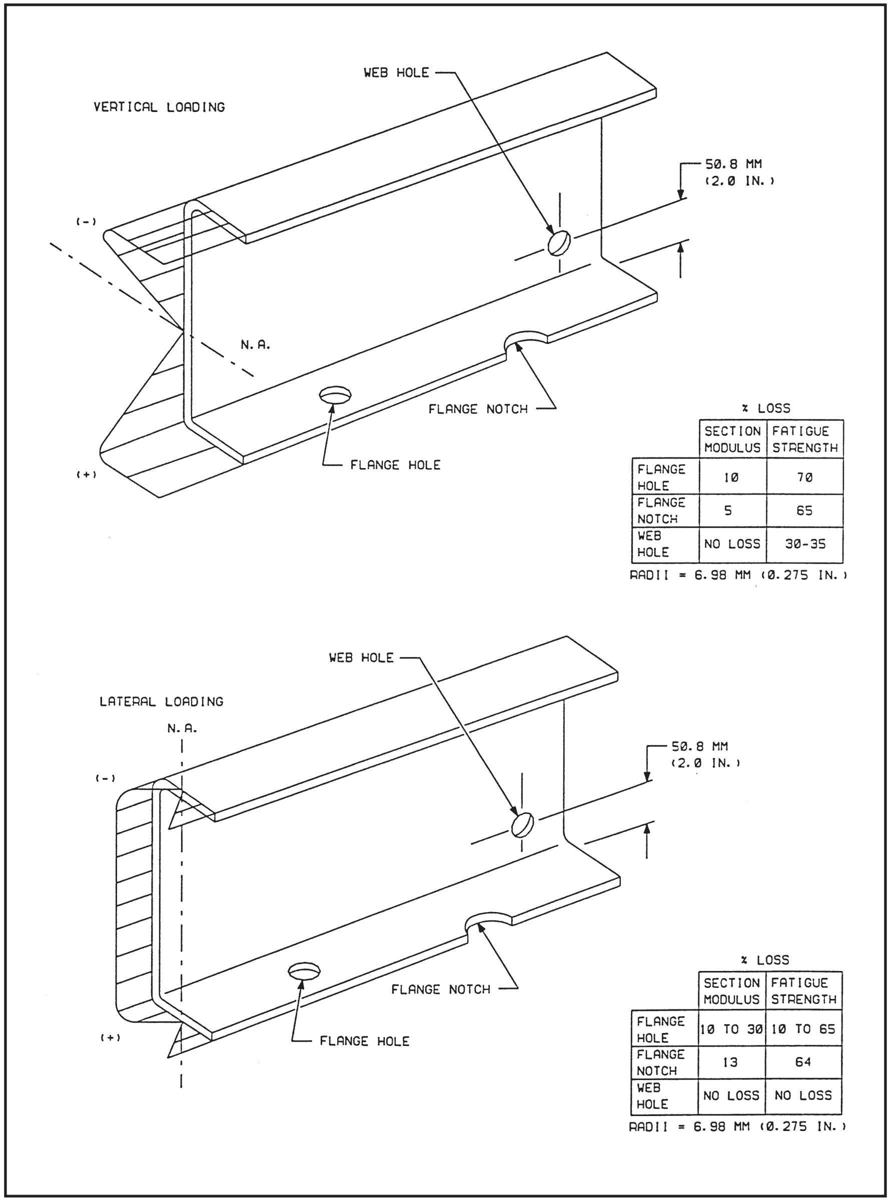


Figure 9

Extending Wheelbase/Moving Axle (cont'd)



% LOSS

	SECTION MODULUS	FATIGUE STRENGTH
FLANGE HOLE	10	70
FLANGE NOTCH	5	65
WEB HOLE	NO LOSS	30-35

RADII = 6.98 MM (0.275 IN.)

% LOSS

	SECTION MODULUS	FATIGUE STRENGTH
FLANGE HOLE	10 TO 30	10 TO 65
FLANGE NOTCH	13	64
WEB HOLE	NO LOSS	NO LOSS

RADII = 6.98 MM (0.275 IN.)

Figure 10

To avoid premature failure, SVMs should observe these general guidelines:

- Use existing holes wherever possible.
- Locate holes no closer to the top or bottom flange than existing holes placed by the chassis manufacturer.
- Avoid placing holes in the lower one-third of the web in the area immediately behind the cab.

Crossmembers

Additional frame crossmembers are required whenever a two-or three-piece driveshaft is used to support the center bearing and shaft. Crossmember design should meet the following criteria:

- Adequate vertical stiffness to prevent resonance with prop shaft imbalance excitation in the vehicle speed range.
- Adequate strength to support the weight of the prop shaft and support bearing, with respect to maximum vertical acceleration of the prop shaft. (Note: Crossmember has adequate strength if stiffness requirement is met.)
- Crossmembers should be rigidly welded, bolted or riveted to the frame rails.
- Designed to avoid retention and other foreign matter.
- Should not protrude excessively below the underbody and frame rails to prevent reduction in ramp break-over and ground clearances.

Extending Wheelbase/Moving Axle (cont'd)

Analyzing Frame Failure Causes

In some cases, such as a vehicle collision, the reason for frame failure is easily apparent. In others, however, determining the cause is considerably more difficult. Frame failures can generally be traced to one of three reasons:

- Vehicle collision
- Excessive bending moment
- Localized stress concentration

Collisions

Failures caused by collisions should be repaired using proper methods and reinforcements as necessary.

Excessive Bending Moment

Overload, improper weight distribution or vehicle misapplication can cause excessive bending moment failures. This type of failure occurs at different areas on different types of vehicles.

Localized Stress Concentration

Localized stress concentration failures may result from bending moment stresses. However, stress levels would not be high enough to cause any difficulty without localized stress concentration points. Localized stress concentration points maybe caused by:

- poor body or fifth wheel mountings
- special equipment or accessory installation
- improper welding or welding methods
- improper reinforcements
- loose bolts or rivets
- defective material

They may also result from high bending loads, coupled with severe torsional loads (e.g., off-road applications).

Fifth Wheel Installation

General Motors recommends attaching fifth wheel or body mounting to the frame rail web section, not through flanges. Refer to the GM Body Builders Manual for proper installation procedures.

! Using U-bolts to attach fifth wheels or bodies is not an approved installation method. Doing so may result in the development of high-stress concentration.

Special Equipment/Accessory Installation

Installing special equipment or accessories can cause high-stress concentrations due to the attachment method or their added weight.

- Never drill holes through flanges.
- Avoid drastic changes to section modulus. Section modulus changes usually occur when large mounting plates are added to support special equipment.
- Avoid mounting heavy equipment across the flanges or on side-rail webs. Doing so may result in stress concentration high enough to cause failure of the nearest crossmember, bracket or other frame stiffener or through a nearby hole in the frame flange.

Extending Wheelbase/Moving Axle (cont'd)

Improper welding or welding methods are a major cause of stress concentration points, which may ultimately result in frame failure. Refer to general welding instructions outlined under “Welding” on page 13 in this section.

Reinforcements

Using improper reinforcements or attachment methods may create localized stress concentrations. This may actually reduce the frame load-carrying capacity to below that of the original frame (i.e., before adding reinforcements). There are five basic types of reinforcement (see Figure 11). Their descriptions follow.

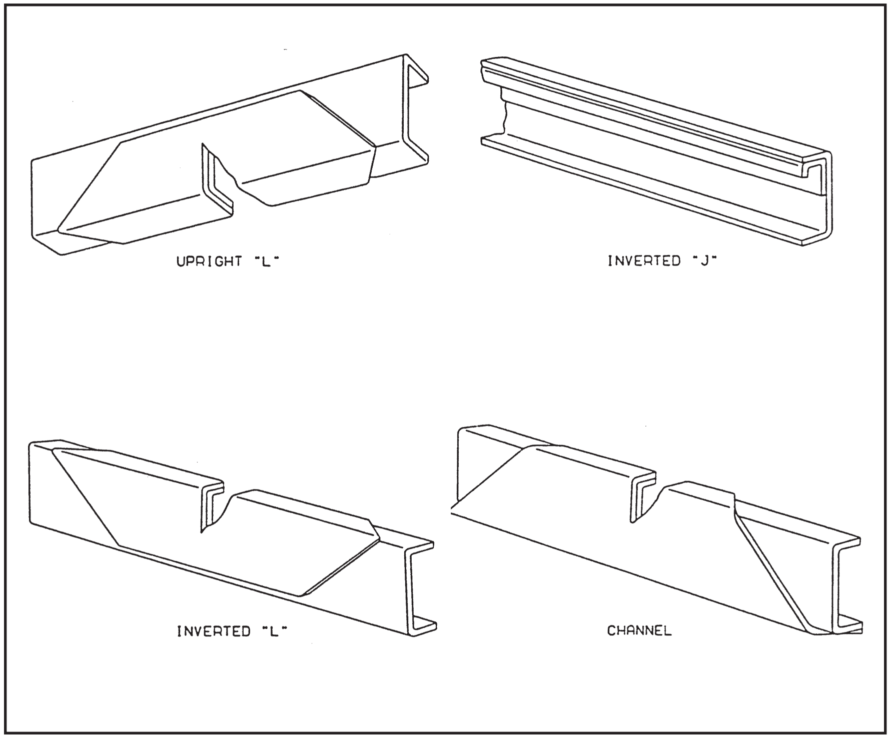


Figure 11

Upright “L” reinforcements should be used in maximum stress locations, at the bottom of the lower flange and where buckling of the upper flange is not a problem. They may be placed either inside or outside the frame side rail. The upright “L” reinforcement is quite versatile and may be used as full-length or short localized reinforcement. However, it may be limited by the configuration of the frame or spring hanger brackets.

Inverted “L” reinforcements also may be used inside or outside of the frame rail. They are recommended where maximum stress is transferred to the upper flange, for example dump trucks with the box in the raised position. This type of reinforcement is easily adapted to frame and hanger bracket designs which prohibit using an upright “L” reinforcement or where the upper flange is subject to buckling.

Channel reinforcements can be used for full-length or localized reinforcement and can be installed inside or outside the frame side rail. Two major disadvantages are their added weight and required installation time. It may also be difficult to place the channel inside or over the existing rail due to manufacturing tolerances, crossmembers or mounting brackets.

Extending Wheelbase/Moving Axle (cont'd)

Terminating Reinforcements

To prevent localized stress concentration, reinforcements must be properly terminated. Reinforcement ends must be tapered or stress relieved. Tapers should not exceed 45 degrees.

! When using several reinforcements together, stagger them so that their ends overlap by 203-255 mm (8-10 in.).

Frame Repair and Reinforcement: General Rules

Specific frame repair and reinforcement procedures vary depending on circumstances and materials. The general guidelines outlined here, however, are very important and apply to virtually all repair and reinforcement situations.

- Always identify the material that makes up the base rail. Reinforcement should be of the same or better material than the base rail.
- Make sure that only fully trained, qualified specialists perform frame straightening and other repairs.
- Always try to identify the cause of the failure.
- Do not attach fifth wheels or body and accessory mountings through frame flanges. Refer to GM Body Builders Manual for additional information.
- Do not drill holes in top or lower flanges.
- Use only proper electrodes as specified for base rail material when welding is necessary.
- Do not use oxyacetylene welding equipment on frames.
- Do not weld reinforcements across the frame flanges.
- Do not weld within 19 mm (0.75 in.) of the edge of a frame flange.
- Remove all notches or weld buildups from flange edge when repairing a broken frame.
- Do not weld cast brackets to frame.
- Do not weld flanges of cracked reinforcements and base rails together.
- Do not patch cracks. Make correct repair and reinforce the area.
- Always scarf reinforcement ends to provide adequate stress relief.
- Always stagger ends of reinforcements by a minimum of 203 mm (8 in.) apart.
- Before welding, disconnect negative battery cable to prevent possible electrical damage to generating system.

Welding

Welding is an excellent attachment or repair method. SVMs, however, must be very careful to use proper welding procedures. Inferior welds and improper methods can cause further frame damage and additional reinforcements may be required later to prevent the problem from reccurring. Refer to the specifications table in Figure 13 for proper welding electrode identification and usage.

WARNING Prior to any welding, disconnect all negative (ground) cable(s) from all battery(ies).

Extending Wheelbase/Moving Axle (cont'd)

Welding Equipment

CAUTION Never use oxyacetylene to weld frame rails.

Electric arc-welding is recommended for steel frame modifications. Shielded Arc Method is recommended because heat generated during welding is localized with minimal burning of material. In addition finished weld can be ground flush and drilled if necessary. Shielded metal arc welding (SMAW); gas metal arc welding (GMAW), also know as metal inert gas (MIG) welding; gas tungsten arc welding (GTAW), also know as tungsten inert gas (TIG) welding; or flux cored arc welding (FCAW) all recommended methods.

NOTE: Weld procedure recommendations:

- Welding can be performed only when surfaces are clean and dry.
- Surface areas and edges to be joined must be clean and free of oil, grease, loose scale, rust, moisture, paint or other material.
- Preheat areas to be welded to avoid craters, notching and undercutting.
- Peen new welds prior to grinding to relieve stresses.
- Grind all weld flush with the surrounding surfaces
- Inspect the weld area carefully after grinding. Grind out any remaining notches or undercuts.
- For welds extending to the edge of the flange, locate a run-off block at the edge to obtain a continuous weld without undercuts. After welding, the run-off block should be cut off.
- Electrodes: Only low hydrogen electrodes should be used; use proper care for exposure and storage.
- Seal weld with rust preventative coating.

NOTE: Welding procedures vary with different frame materials. Issues resulting from weld modifications to chassis / frame may not be covered by warranty. Altering the wheelbase of a vehicle may affect frame resonant frequencies. Frame stiffening may be necessary to avoid undesirable frame flex.

Identification of Frame Rail Material

Chassis are manufactured with frame rails of alloy steels, including heat-treated reinforced versions. Frame material must be identified before attempting frame modification.

Chassis are manufactured with frame rails of:

- High strength low alloy steel (HSLA) 40,000 Mid-Size Truck, 33,000-60,000 LD/HD Truck and 60,000-80,000 Med-Duty Truck; PSI yield strength.
- Heat-treated steel (HT) 100,000- 120,000; PSI yield strength.

Extending Wheelbase/Moving Axle (cont'd)

Welding Methods

Four basic welding types (Figure 12) are used to repair and reinforce frame rails. These methods can be used with any type of material.

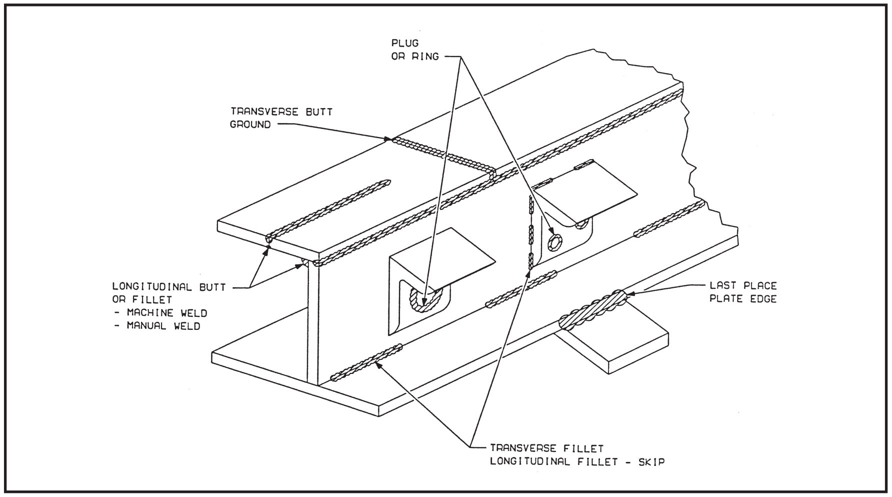


Figure 12

- **Continuous Fillet (Longitudinal Butt) Weld** — This is used to weld a continuous bead along a reinforcement on the frame rail web section, or to add gussets or plates to crossmembers. Continuous fillet welds should never be made across frame flanges or along their inside edges. When welding in a flat position, use high range of electrode current. For welding overhead or in difficult areas, use low range of electrode current. Use the voltage specified for the electrode.
- **Groove Welding** — This basic repair weld is also called transverse butt ground welding. It is applied after grounding the surface for good penetration. When welding cracks, make sure to cross either the upper or lower flanges. Weld completely and then grind off excess weld to remove notches or weld buildup on the flange edge. Use medium range of electrode current.
- **Plug Welding** — Plug (or ring) welds are good for attaching reinforcements because they eliminate the possibility of loose-fitting bolts. Be careful, however, to properly place plug welds in different types of reinforcements. GM highly recommends E-7018 electrode for plug welding because of its good penetration and light coating. Use high range of electrode current and appropriate voltage for flat or vertical plug welds. Overhead plug welding is very difficult. Do not use this method unless other approaches are impractical. Then use high range for first pass and complete plug at medium range. Refer to plug weld table (Figure 13) for hole size to use for material thickness variations.
- **Stitch (Intermittent Fillet) Welding** — This type is also called transverse or longitudinal fillet. It is not generally used on frames because continuous fillet welding provides better attachment. Stitch weld when warp and heat control is critical, using medium range of electrode chart.

For all types of welding, make sure to:

- Connect welding machine ground cables as close to work area as possible.
- Use smaller diameter electrode whenever possible, and make several passes rather than large diameter and single passes.

! Vehicle load capacity depends on strength and rigidity. For effective repairs, make sure that frame service is performed only by qualified personnel using proper materials and equipment.

Dissimilar Metals

To prevent a chemical reaction, apply a barrier coating of good corrosion-inhibiting compound to all faying surfaces of dissimilar metals. Remove old sealer with a putty knife.

! Before stripping the vehicle down for repair, make sure to support the frame on a smooth, level floor. This will permit frequent checking for alignment during the straightening and replacement process.

Extending Wheelbase/Moving Axle (cont'd)

High Strength Low Alloy Steel Frame Weld Recommendations (40,000 - 80,000 PSI Yield Strength)
Any of the electric arc methods previously described may be used (see Page 14). The choice of an electrode or wire depends somewhat upon welding equipment available and method selected.

The SMAW and GMAW methods (see below) are preferred for welding HSLA frames. Use of low hydrogen electrodes is recommended. Refer to Tables 1 and 2 for selection of recommended electrodes and wires and refer to A.W.S., A.5 standards from: American Welders Society, 2501 N.W. 7th Street, Miami, FL 33125 (www.aws.org).

Table 1: SMAW Method (HSLA Frames)

Position	Electrode Sizes Inch	Amperes	Volts	Speed (inch/Min.)
Flat	0.125	—	—	—
Horiz & Vert	0.125	110/140	20/14	24

Table 2: GMAW Method (HSLA Frames)

Position	Electrode Sizes Inch	Amperes	Volts	Speed (inch/Min.)
Flat	0.035	—	—	350/400
Horiz & Vert	0.035	190/220	20/30	350/400

Heat Treated Frames Weld Recommendations (100,000 - 120,000 PSI Yield Strength)

Note: When welding 100,000 - 120,000 PSI yield strength Heat Treated Frames use SMAW method with low hydrogen electrodes (refer to table 3) that meets or exceeds AWS-E-11018.

Table 3: SMAW Method (HT Frames)

Position	Electrode Sizes Inch	Amperes	Volts	Speed (inch/Min.)
Horiz & Vert	0.093	21/24	2.0	75-115
Horiz & Vert	0.125	21/24	2.5	90-160
Horiz & Vert	0.156	21/24	3.9	130-220
Horiz & Vert	0.187	21/24	5.1	200-300
Horiz & Vert	0.250	21/24	7.8	300-400

Extending Wheelbase/Moving Axle (cont'd)

Driveshaft (Propshaft) Extension

The driveshaft can be extended, using a single-length or multiple-piece driveshaft. It is important to develop and follow proper design and installation guidelines for this process.

Driveshaft Extension Design

The most important objective is to design driveshaft extensions that efficiently transfer power from the transmission to the rear axle assembly (Figure 13). For higher durability and reliability, General Motors recommends using only graphite driveshafts manufactured with driveline tubing.

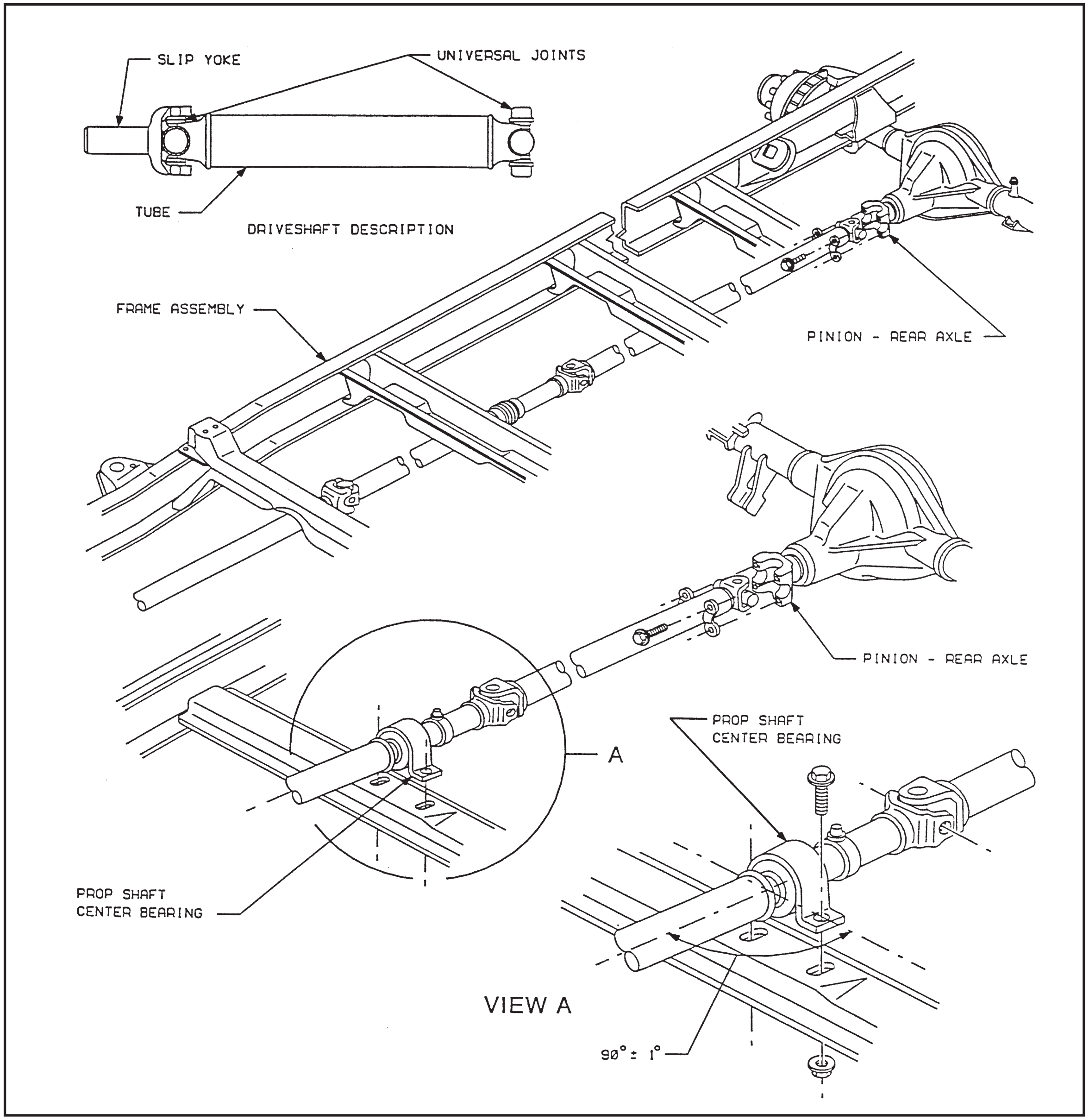

SLIP YOKE
UNIVERSAL JOINTS
TUBE
DRIVESHAFT DESCRIPTION
FRAME ASSEMBLY
PINION - REAR AXLE
PINION - REAR AXLE
PROP SHAFT CENTER BEARING
A
PROP SHAFT CENTER BEARING
VIEW A
90° ± 1°

Figure 13

Extending Wheelbase/Moving Axle (cont'd)

Two-Piece Driveshaft Bearings

For two- or three-piece driveshaft applications, use an in-line bearing assembly. Figure 14 shows a typical two-piece driveshaft.

Recommended bearing locations vary with vehicle stretch length. If the driveshaft exceeds 1,524 mm (60 in.), use a two-piece assembly with an in-line bearing assembly. Keep the driveshaft lengths as close to equal as possible.

- SVMs should devise a gauge by which to measure driveshaft alignment angles for front and rear shafts. For smooth operation, the front must align with the rear shaft in both side and plan views (Figure 15). Check for this vertically and along the horizontal center line (Figure 16).

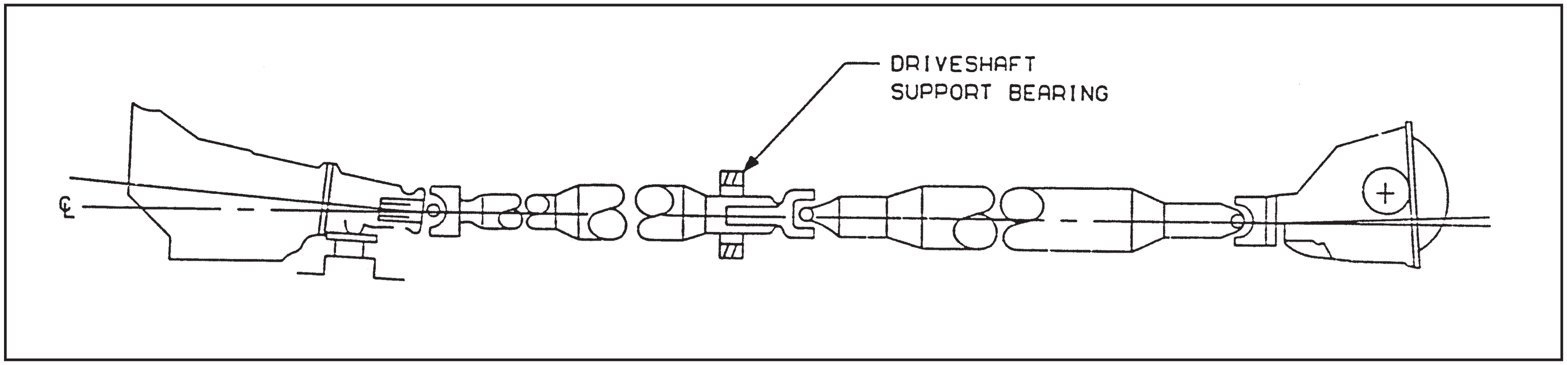

DRIVESHAFT SUPPORT BEARING
℄

Figure 14

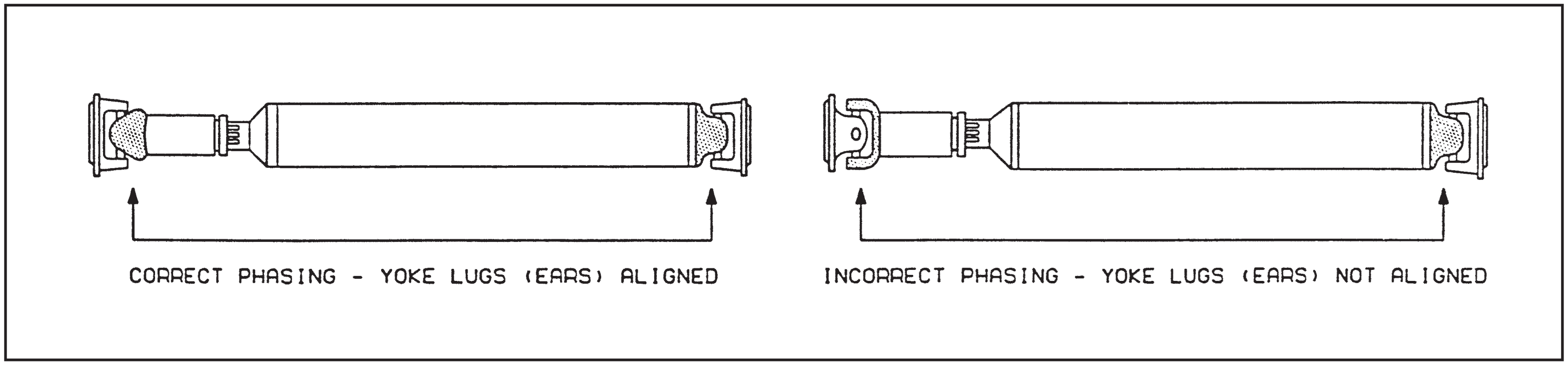

CORRECT PHASING - YOKE LUGS (EARS) ALIGNED
INCORRECT PHASING - YOKE LUGS (EARS) NOT ALIGNED

Figure 15

Extending Wheelbase/Moving Axle (cont'd)

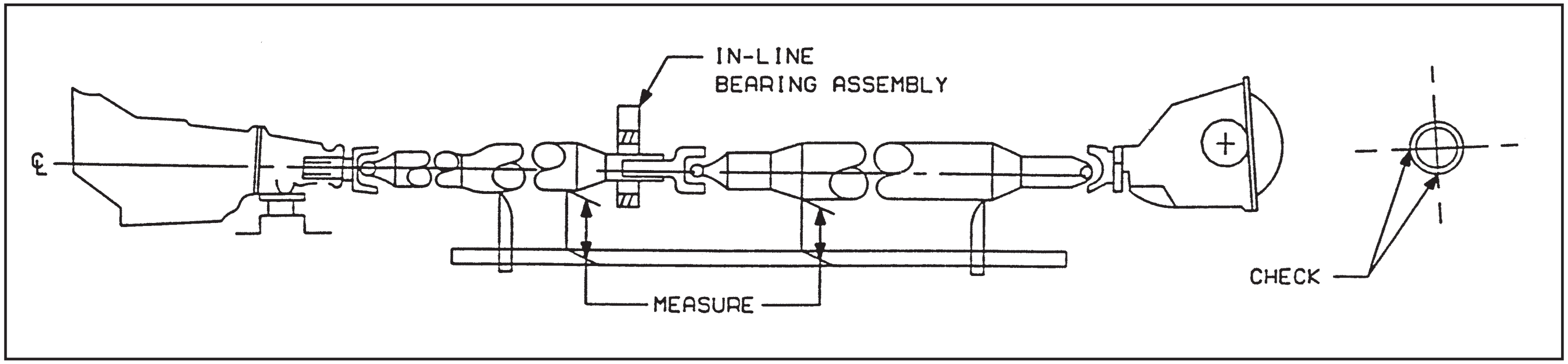


Figure 16

- For maximum support, mount bearing assembly to a cross-member. Final driveshaft alignment must allow vertical and horizontal bearing adjustment.
- Make sure to protect the in-line bearing from common operating conditions such as weather and road debris. General Motors recommends mounting a protective bridge between the bearing assembly and the ground. Fasten the bridge with bolts to facilitate serviceability.
- Splicing driveshaft tubes is not recommended. Splice welds create irregularities on inner and outer surfaces, making it difficult to balance the driveshaft. Additionally, splice welding may cause embrittlement, increasing the possibility of driveshaft failure.
- Protect the driveshaft and universal joints from common operating conditions (e.g., potholes), by mounting heavy-duty frame cross-members between the driveshaft and the road surface.
- The driveshaft should be dynamically balanced at 25/65 mph (40-105km).

! Use only General Motors or equivalent parts for driveshaft installation and service.

For additional information, refer to SAE J901 (Universal Joint and Driveshafts — Terminology — Application).

Universal Joint Angles and Phasing

When an ordinary universal joint is operated at an angle, the driven yoke fluctuates slightly in speed as the joint rotates. That is, although the driving yoke rotates at a constant speed, the driven yoke speeds up and slows down twice per revolution. This fluctuation of the driven yoke is in direct proportion to the angle through which the universal joint is operating. The greater the angle, the greater the fluctuation.

This fluctuation and resulting vibration can be eliminated by phasing the universal joints at each end of the shaft so that the alternate acceleration and deceleration of one joint is offset by equal and opposite accelerations of the other joint. Correct phasing is achieved by aligning the universal joint lugs on each end of the shaft (refer back to Figure 15).

Extending Wheelbase/Moving Axle (cont'd)

Universal Joint Angles and Phasing *(cont'd)*

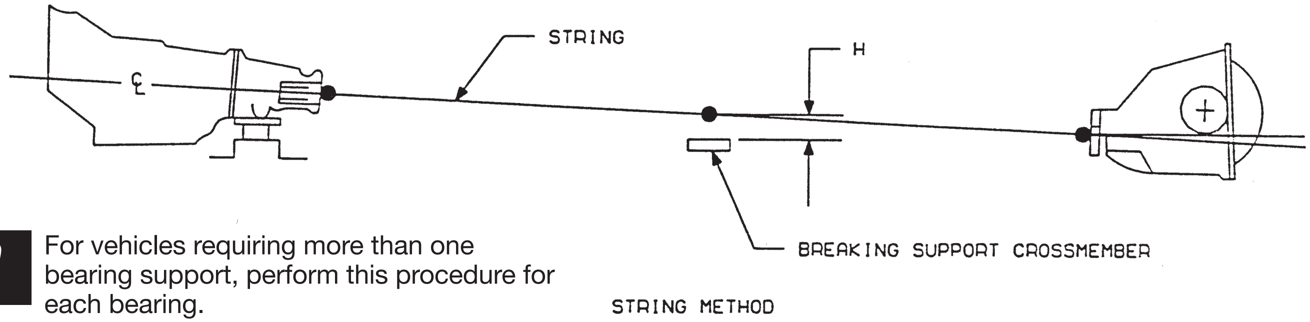
To allow the propshaft to operate as smoothly as possible, make sure that the input universal joint is approximately equal and opposite to the output universal joint angle. That is, the downward angle (a) of the transmission output shaft, relative to the driveshaft axis must be equal to the downward angle (b) of the pinion as shown in Figure 16. (**Note:** Angles shown are exaggerated for clarity.) To allow the best compromise for the pinion angle as it changes because of vehicle loading, acceleration and ride motion, these angles are determined and set at the factory. This eliminates the need for adjustment by the SVM.

Universal joints are designed to operate safely and efficiently within a 3-degree joint angle. Exceeding this design limit may break the joint or cause excessive driveline vibration.

Multiple-Piece Driveshaft Alignment Procedure

The bearing supporting the driveshaft must be positioned vertically and laterally so that driveshaft segments are all in a straight line between the transmission output yoke and differential input flange. The following recommended procedure should enable SVMs to properly align the driveshaft, regardless of build variation.

1. After extending the vehicle, install the driveshaft bearing support crossmember (without the driveshaft or support bearing).
2. Position the vehicle on a drive-on hoist or otherwise allow it to rest fully on the tires, so that the rear suspension is at curb height.
3. Attach one end of a string from the center of the transmission spline as indicated to the center of the pinion attachment flange. Pull string taut.
4. Measure the vertical distance from the center of the bearing mounting area of the crossmember to the string (dimension H, Figure 17).
5. With a square just contacting the string in the lateral directions, mark the crossmember to indicate the correct lateral position of the center of the bearing.
6. Add shims under the bearing so that the center height of the bearing is equal to the measurement taken in step 5. Mark the base of the bearing to indicate its lateral center.
7. Remove string. Install bearing and driveshaft with shims under the bearing so that its center aligns laterally with the mark on the crossmember. The bearing center should be at the same point as the string. For vehicles requiring more than one bearing support, perform this procedure for each bearing.



! For vehicles requiring more than one bearing support, perform this procedure for each bearing.

Figure 17

Occupant Body Mounting

Optimum body-mount location varies by frame wheelbase length. The best locations, for effective isolation from road vibration, are those closest to frame crossmembers and underbody crossbars. For optimum load-distribution isolation, additional body mounts should be no farther apart than 762 mm (30 in.). When designing and locating body mounts, SVMs should also consider serviceability and the recommendations outlined in the “General Requirements” section that follows.

General Requirements

To maintain base vehicle performance, it may be necessary to add, change or move body mounts along the frame. General Motors recommends the following practices for SVM-added body mounts:

- Use only GM or equivalent body mounts. Use OEM rubber body isolators, frame/body rails and/or outrigger brackets on the frame vertical side web.
- Avoid mounting bodies directly to the top of the frame. Doing so restricts frame torsional flexibility. It may also promote body cracking and provide a direct path for chassis noise, vibration and harshness (NVH). Figure 18 shows typical body mounts.
- Never weld body supports directly to the frame flanges. Do not weld body structures directly to frame extensions behind the rear suspension. Use consistent body attachment methods along the entire frame length.
- Use reinforcements or filler blocks where mounting devices may deform frame flanges. Mounting devices must be locked units that minimize loosening, but can be retightened if necessary. Use grade 8 PTN nuts.
- Correctly position all body mounts directly under cargo body crossmembers or longitudinal members to prevent body fatigue failures.
- Ambulance and other sensitive-cargo bodies require reduced stress on the body and frame. To accomplish this, minimize height above the frame and isolate the compartment from noise and vibration. Use full-floating, automotive style rubber body mounts or other chassis manufacturer-approved body mount systems. For bodies up to 3708 mm (146 in.) in length, install a minimum of four per side; for longer bodies, at least five per side.

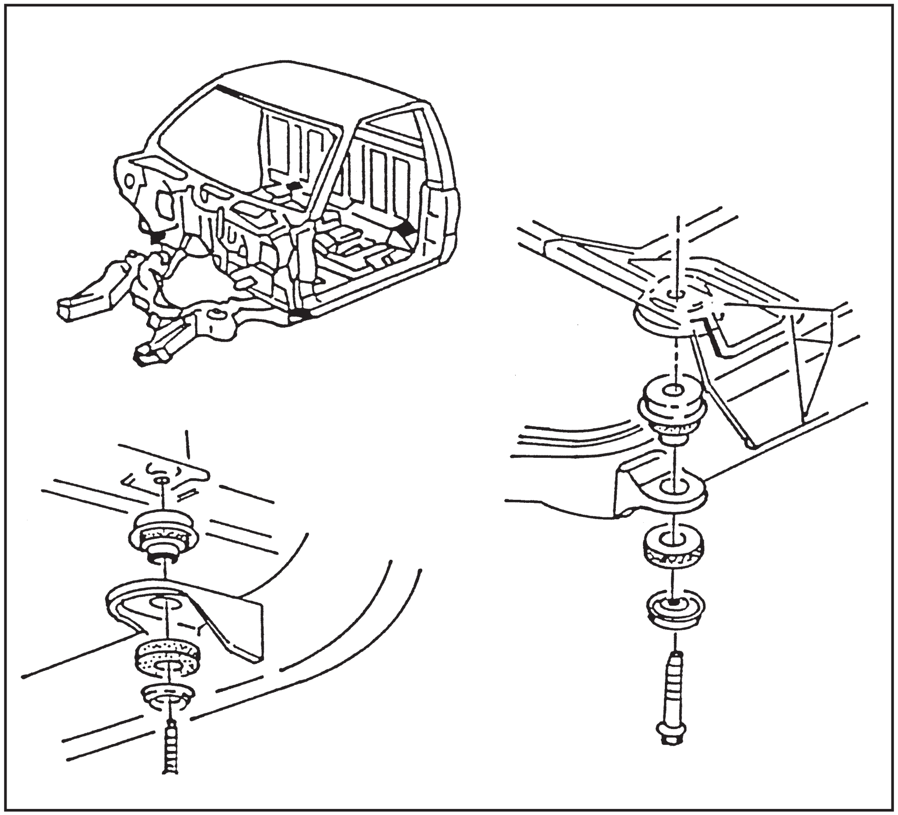


Figure 18

Upfit Body Mounting

! Design body-mounting schemes that comply with recommended GM guidelines (see GM Body Builders Manual), NTEA Industry Standards and Federal Government Mil-Std Specifications.

Body Mounting Considerations

To ensure ease of maintenance and service, SVMs must provide access to frame crossmember located over the transmission, rear shock absorber crossmember, all batteries, and the fuel tank. There should also be adequate clearance between the rear tires and the body structure to prevent interference with suspension movement.

GM also recommends the following:

- Avoid installing equipment such as loading cranes and supplementary tanks on only one side of the vehicle.
- Position body sub-frame evenly on the vehicle side rail top flanges. Taper the forward ends of the body mounting frame side member to provide a smooth transition to the vehicle chassis frame.
- Avoid using welding straps or other structures between the body and frame that can ground out the elastomeric body mounting system. SVMs should use rubber shock isolation dampers (“hockey puck” discs) which are designed for higher control of quality, durability, squeak and rattle.
- Avoid body mount designs and modifications/ additions that interfere with travel of the axle or leaf spring up to the full metal jounce position.

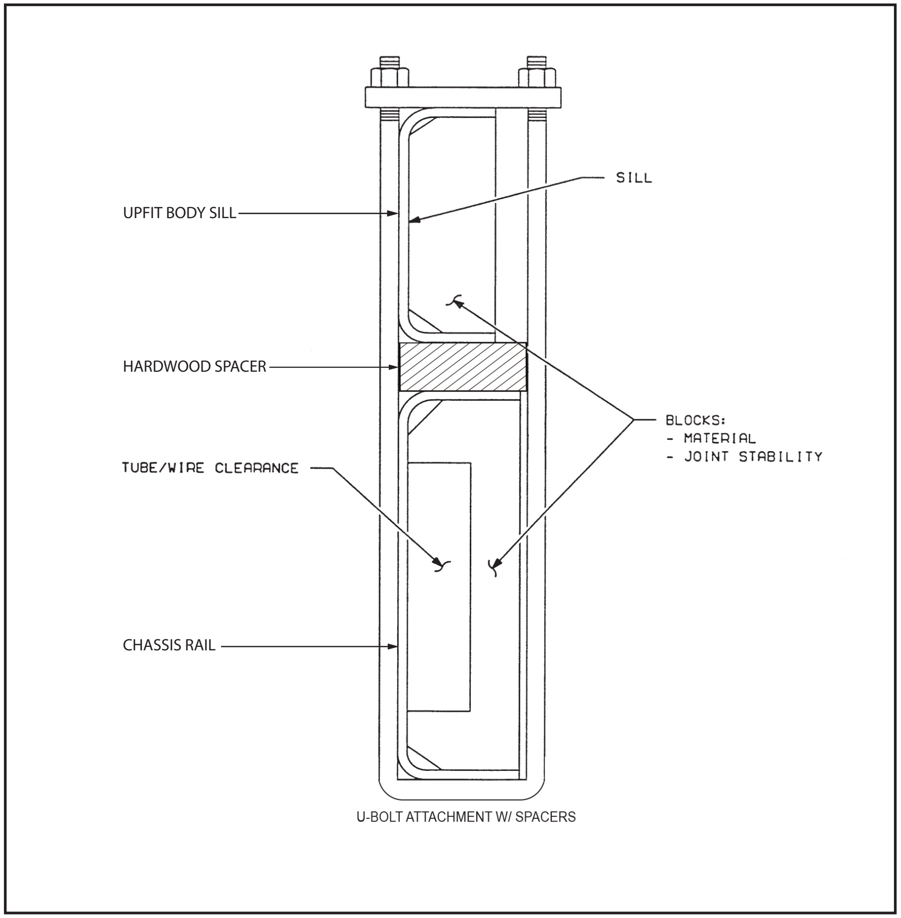
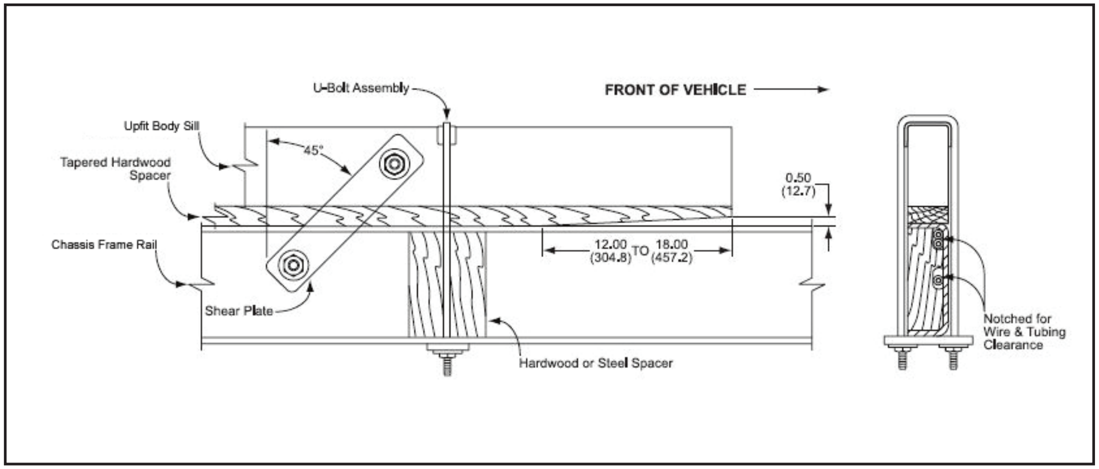


Figure 19

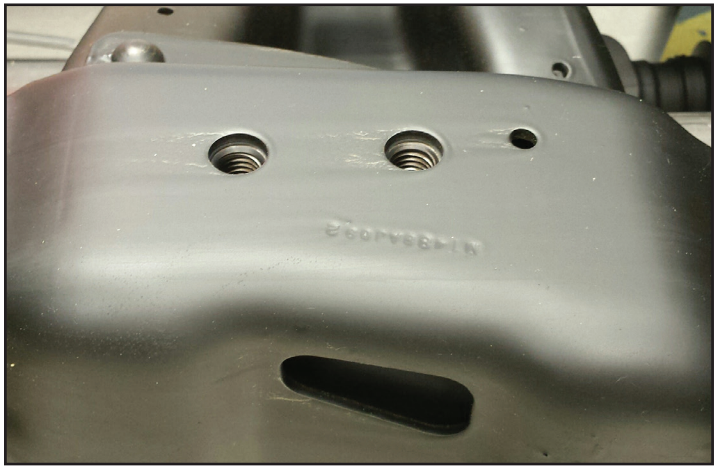
Body/Equipment Attachment Methods

Using U-bolts and clamping eliminates the need to drill and weld the frame, and is generally the least expensive attachment method. When using this method, be sure to block the channel side rail to prevent the flange from collapsing when the U-bolts are tightened (see Figure 19).

Upfit Body Mounting (cont'd)



Common Upfit Body To Frame Mounting Figure 20



Upfit Body Frame ZW9 Attachment Provisions Figure 21

Use spacers between the subframe and the chassis frame as shown in Figure 20. Make sure that spacers do not interfere with plumbing or wiring routed along the frame rail and do not weld them to the frame flanges. Metal spacers are preferred as wood can shrink and drop out.

Clamping devices offer potential savings in both cost and installation time. Some equipment manufacturers have already incorporated clamped attachments into their designs because of these benefits. Since U-bolts and clamping devices depend on friction and a maintained clamping force for attachment, a positive bolted connection should also be used for security.

Bolted attachments are generally preferred over welding because they retain more strength and are more easily serviced.

Body Mounting

SVMs should observe the following recommendations for body mounting:

- U-Bolts(Type1&2) are commonly used for securing upfit bodys, should not be used on down turned flanged frames nor in sloped sections. No notching frames for U-Bolts, use steel or hardwood anti-crush spacers to protect flanges.
- Mechanical attachment(Type 3), use Grade 8 Bolts/Nuts for upfit body Mechanical attachments. Use available frame attachment provisions. (see Figure 21)
- Shear Plates(Type 4) should be located at front & rear(aft of rear spring hanger) of upfit body span on chassis.
- Use hardwood anti-crush spacers & elastomeric rubber to meet upfit body to frame damping requirements.
- No upfit body to frame attachment welding in high stress areas. Welding allowed aft of rear spring shackles only.
- Provide upfitter specific maintenance communication for mechanically fastened upfit body attachments requiring periodic inspection.

Upfit Body Mounting (cont'd)

Prevailing Torque Nuts (PTN)

Prevailing torque nuts (PTN) have an interference fit on the threads. The interference fit prevents the nut from loosening after it is tightened, eliminating the need for cotter pins or lock washers. PTN fasteners are recommended for several body-mounting applications.

NTEA Recommended Body-Mounting Practices

The National Truck Equipment Association (NTEA) advises that proper body mounting practices and materials are necessary in order to avoid damaging the frame side rail and body. This can occur when load and chassis movement cause uneven distribution of stress and strain.

Attention to proper mounting and specifications is also critical to maintaining vehicle ride and handling characteristics.

The NTEA Body Practices Subcommittee has reviewed the mounting methods of several chassis manufacturers and has identified four general types.

Type 1 — U-Bolt mounting method uses U-bolt/threaded rod and end plate to secure the body's longitudinal mounting rails to the chassis frame. Fillers or strips of hardwood or hard rubber act as cushions between the longitudinal mounting rails and the chassis frame. Secure the filler to frame or rail with steel banding or equivalent. The hardwood filler should taper approximately 1 inch per foot, starting at the front end and extending about 300 mm (11.8 in.) (Figure 19 & 20) back. The first tie-down should be positioned no more forward than the rear edge of the taper. For longitudinal body control, secure the shear plates with grade 8 bolts or weld them to the longitudinal mounting rails. Prevailing torque nuts are preferred in all threaded connections over double nuts. Spacers (preferably metal) placed between the flanges of both the longitudinal mounting rail and the frame at each tie-down will prevent the flanges from collapsing. Two guide plates (see Figure 27), one on each side at the front, will prevent lateral shifting of the body. This type of mounting is generally suitable for non- or semi-rigid bodies.

Type 2 — Brackets and Pinch Bolts in this method are fabricated and/or formed brackets of angles welded and/or bolted to the longitudinal mounting rails and chassis frame. A bolt pinches the brackets together to secure them. A filler, cushion or strip (preferably of hard rubber) may be used between the longitudinal mounting rails and the chassis frame. If so, it should be secured to prevent loss or movement.

SVMs should specify the zone or area between the back of the cab and rear axle(s) where spring mounts should be used. Shear plates should be bolted or welded to the body longitudinal mounting rails and bolted to the chassis web, but not in top flanges. (**Note:** Use grade 8 fasteners to secure the shear plates.)

Prevailing torque nuts are preferred in all threaded connections (instead of double nuts).

Type 3 — Rigid Mounting & Semi-Rigid
This category includes industry practice of mechanical attachment to frame flanges using already existing holes including pickup box attachment points. Intended for vehicles under 15,000 pounds GVWR with service/utility bodies.

Type 4 — Shear Plate Mounted
This mounting type is used to attach non-rigid subframes to OEM frames (Figure 22 & 25). Non-rigid body types include platform, stakebed, dump, rollback carriers and open-top grain/livestock bodies. Multiple fasteners should be used at frame attachment.

Upfit Body Mounting (cont'd)

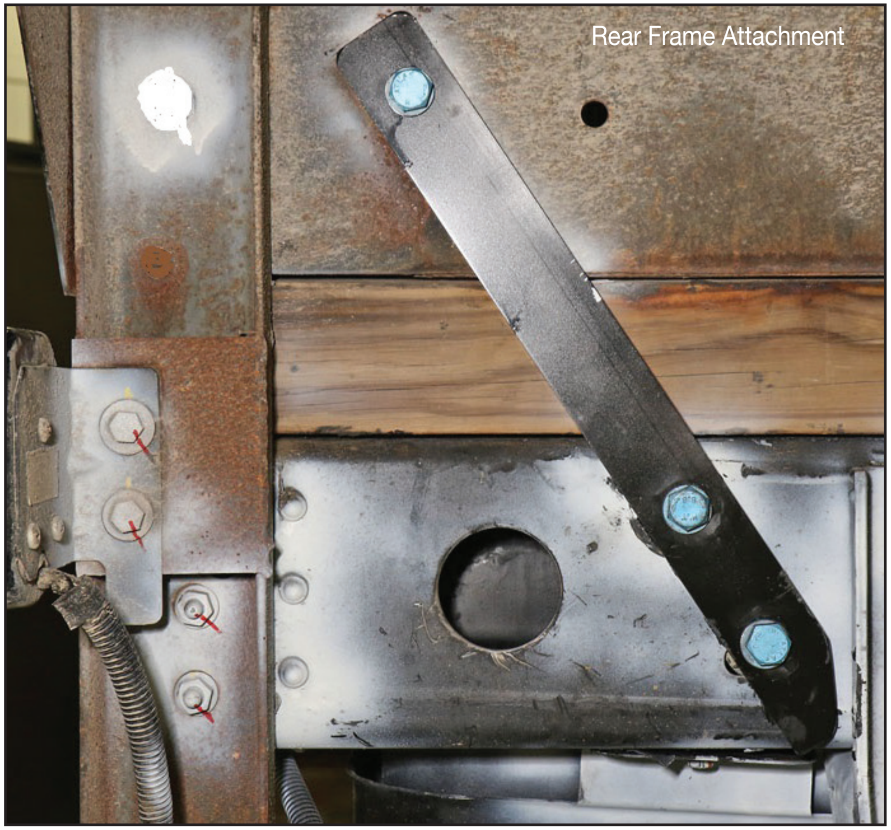


Figure 22

NTEA Body Classifications

The NTEA Body Practices Subcommittee defines vehicle body types in terms of torsional rigidity, grouping them into four basic categories:

- Non-rigid
- Semi-rigid
- Rigid
- Super rigid

The degree of rigidity determines the appropriate attachment method. The table below lists the torsional rigidity of selected body types.

Torsionally Flexible Bodies

Bodies with wood or metal sill construction are considered torsionally flexible. When mounting torsionally flexible bodies, consider the following points:

- The sill should rest directly and squarely on frame side rails. Wood sills must be chamfered 13 mm (0.5 in.) at the front end, tapering to meet the frame approximately 300 mm (11.8 in.) from front end of sill (see Figure 27).
- Sills must not overhang outside of frame. If wood sill is not as wide as frame flange, install spacer blocks at hold-down. Wood grain of blocks should be parallel (up and down) with hold-down.

Torsional Rigidity Of Selected Body Types

Body Mounting	Non-Rigid	Semi-Rigid	Rigid	Super Rigid
Service				
High/with Top			•	
Low/without Top		•		
Platform	•			
Dry Freight Van Body				
Rollup Door		•		
Swing Door			•	
Dump Bodies	•			
Wreckers		•		
Rollback Carriers	•			

Body Mounting (cont'd)

- Mountings must be spaced to clear suspension and any other parts attached to frame side rail. Use U-bolts 13 mm (0.5 in.) minimum diameter for each mounting. One mounting should be located at the front end of sill (at or as close to rear end of taper as possible), one near the rear end and others should be spaced as nearly equally as possible between front and rear mountings. Do not mutilate the frame side rails in any way to accommodate mountings.

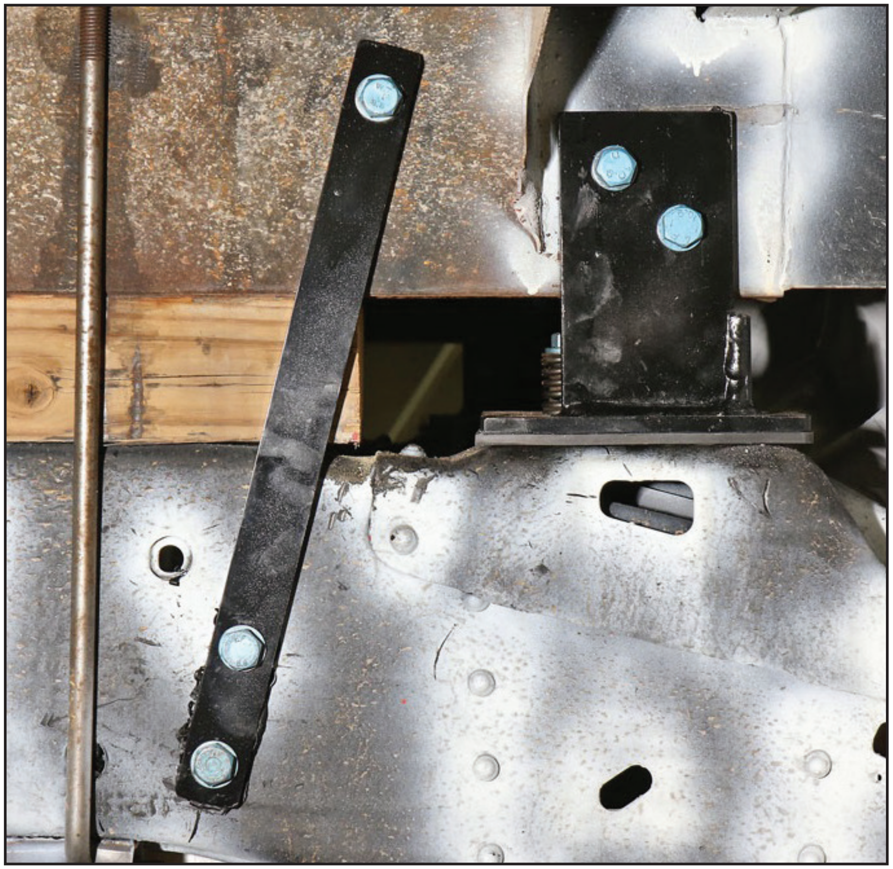


Figure 25

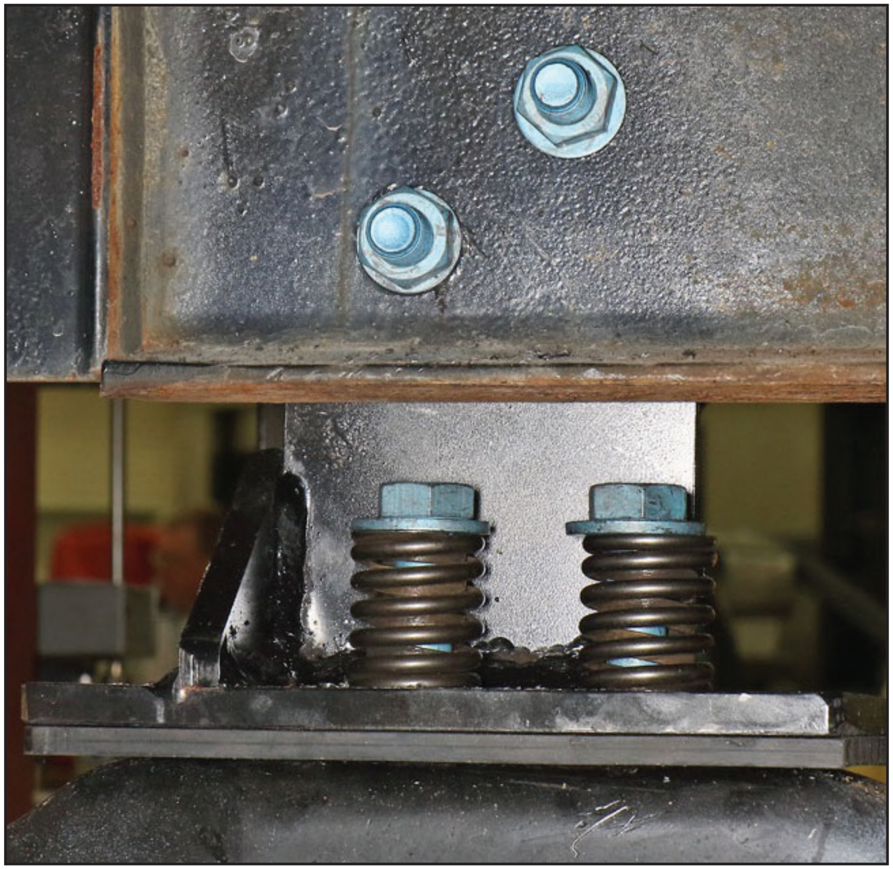
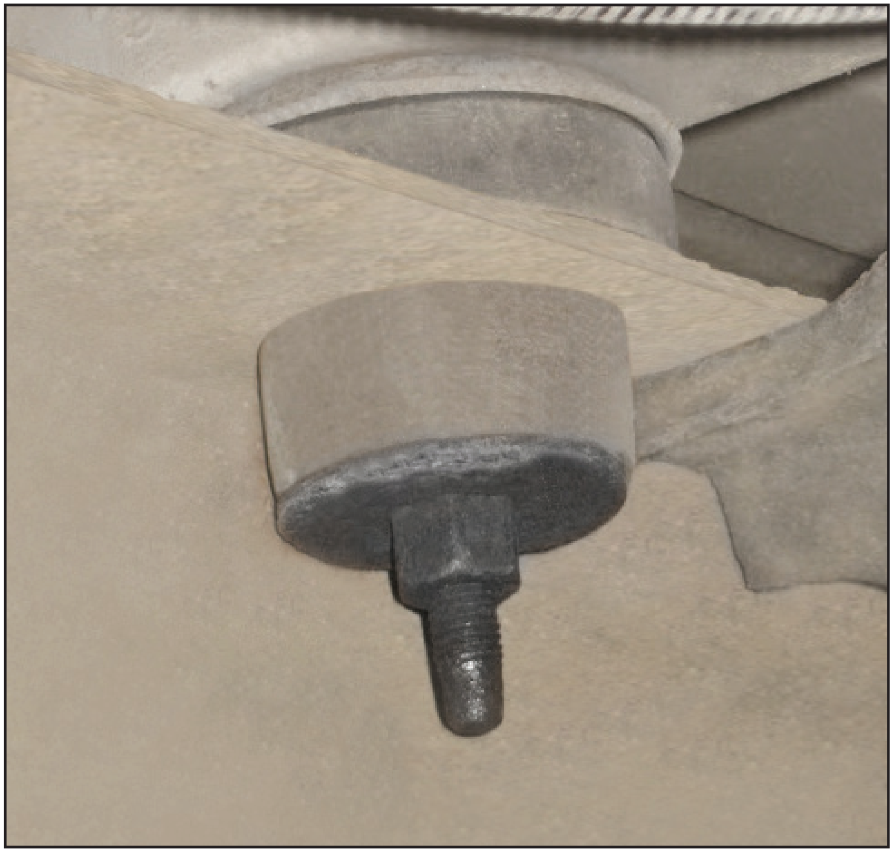


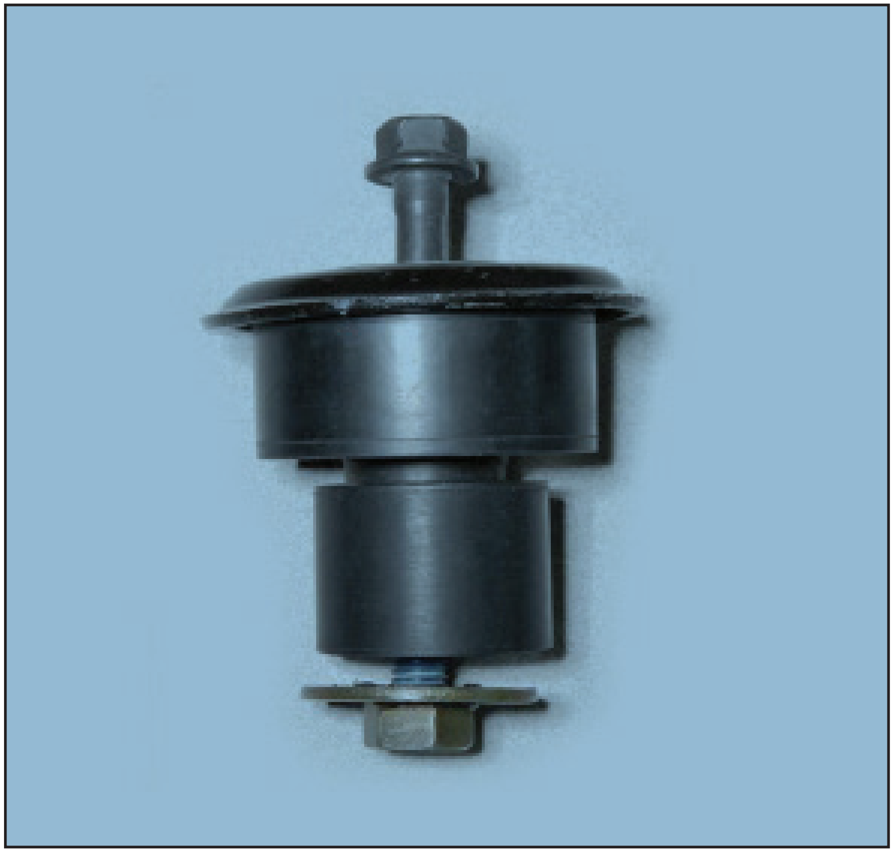
Figure 26

Combination U-Bolt, Shear Plate & Spring-loaded Forward Mount (ZW9)

Upfit Body Mounting (cont'd)



Upfit Body Frame Attachment Cutaway Van Chassis Figure 23



Cutaway Van Body Trunnion Mount Figure 24

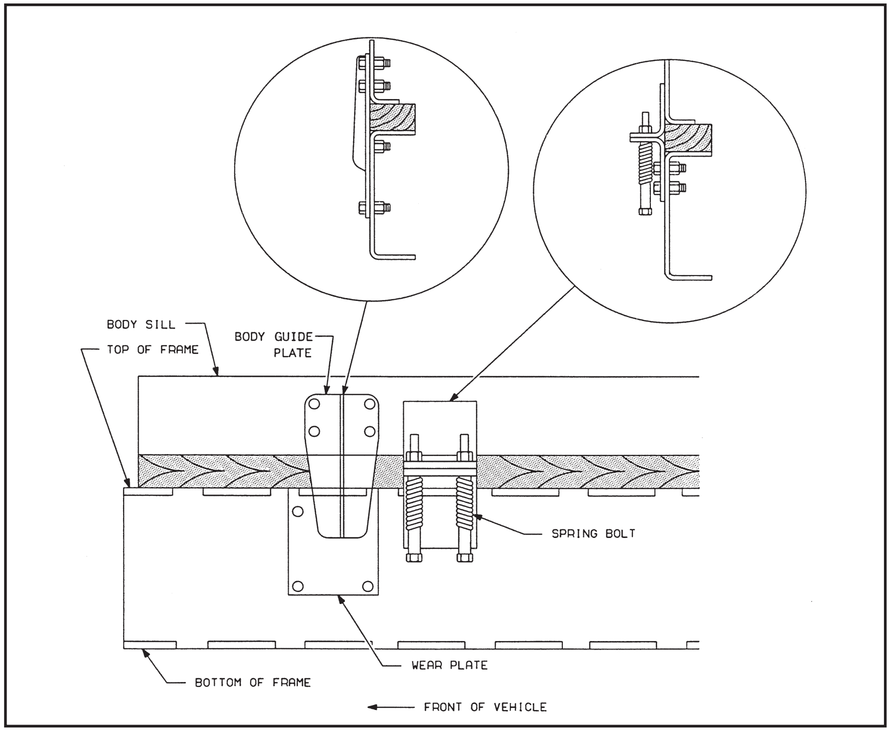
Torsionally Rigid Bodies

Because of their solid construction, torsionally rigid bodies require a more flexible mounting. Trunnion and spring-loaded body mountings provide optimum frame and body life.

Upfit Body Mounting (cont'd)

When mounting a body of this type, SVMs should follow these guidelines:

- Use a hardwood spacer, with a minimum thickness of 19 mm (0.75 in.) between the body sill and frame side rail. Make sure the spacer is chamfered 13 mm (0.5 in.) at the front end and tapered to meet the frame approximately 300 mm (11.8 in.) from the front end of the spacer.
- Use a body guide (Figure 27), to restrict lateral movement of the body and relieve shear stress on mountains. Bolt or weld the body guide to the body sill near front end of the body. It should extend below the body sill and contact the wear plate bolted to the frame side rail.
- Use spring-loaded, angle-type mountings (Figures 26 & 27). They may be bolted or welded to the body sill. However, always use bolts to attach them to the frame side rail. Do not weld directly on the frame side rail. Position mountings to allow a clearance of at least 6 mm (0.25 in.) between upper and lower brackets. Use SAE Grade 8 or Class 10.9 metric bolts with PTN nuts. Spring-loaded mounting bolts also require PTN nuts. The springs should be as short as practical, allowing preloading which will help prevent excessive "body roll" during operation, and a minimum of 25 mm (1 in.) at the front of the body before becoming solid.
- Trunnion-type body mountings also provide flexibility and are acceptable substitutes for the spring-loaded type. (Figures 23 & 24)
- Locate bolts (13 mm/0.5 in. minimum diameter) near the rear of the body sills. Before final attachment, make sure to allow clearance of at least 1.5 mm (.06 in.) between upper and lower shear plates.



Upfit Body Guide Plate and Spring Mount Figure 27

Shear Plate Attachments

Whenever possible, use existing holes to attach shear plates to the frame side rails. When additional holes are required, make sure they are no larger than 20 mm (0.75 in.) in diameter. Drill holes at least 63.5 mm (2.5 in.) apart, in web area only (not in top/bottom flanges).

For holes drilled forward of the rear axle, make sure their centers are no closer than 63.5 mm (2.5 in.) from the top or bottom flanges, and 89 mm (3.5 in.) from any suspension attachments.

For holes drilled rearward of the rear axle, the centers must be at least 51 mm (2.0 in.) from the top or bottom flange and 89 mm (3.5 in.) from suspension attachments.

Fuel Systems

The fuel system includes the fuel tank, metering, lines (including purge control solenoids) and canister(s). Proper sealing is critical to the integrity and overall operation of the fuel system. The SVM assumes complete responsibility for any modifications or alterations to the fuel system. This includes responsibility for system reliability and performance as well as compliance to FMVSS 301 (CMVSS 301).

CAUTION

General Motors recommends that SVMs DO NOT ALTER THE FUEL SYSTEM IN ANY WAY. When delivered, the vehicle fuel evaporative emission control equipment is certified in compliance with Federal and California Vehicle Emission Standards. Any alteration to systems or components and their location could void compliance.

Systems include:

- Fuel tank, metering unit, taps, lines including purge control solenoids and canister or canisters.

Environment Includes:

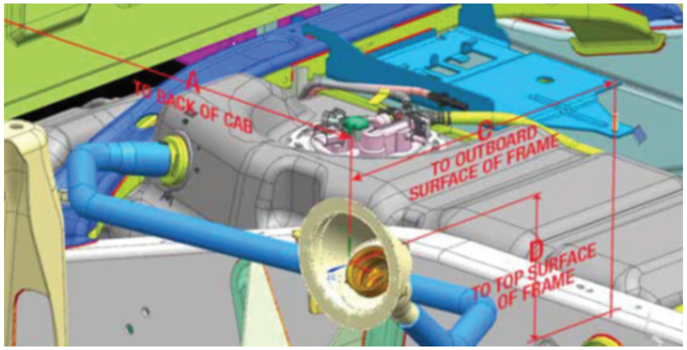
- Heat sources, heat shields, system component relocation.

Fuel Fill

General Motors recommends the following fuel-fill guidelines:

- Fuel tank filler pipe location should be so situated and constructed as to prevent gasoline vapor from emitting to vents of pilot flamed devices.
- Locate and mount the fuel tank filler pipe so as to prevent vapor from entering the body and engine compartment air inlets.
- Minimum clearance between fuel fill/vent system of 20mm to body components. Minimum clearance between fuel fill/vent system of 10mm to chassis components.
- Properly route and secure the fuel fill/vent system to prevent failure due to wear and fatigue. Fuel fill/vent system clamps are to be tightened to OEM spec torque.
- The fuel fill/vent system must be routed so there are no sags or kinks. Excess hose may be removed. There should be a minimum of 6 degree of downward slope in the fuel fill/vent system at any location. There should be a minimum 7 inches in elevation as measured from the fuel cap end of the fill pipe to the fuel tank inlet or fuel height within the tank, whichever is higher. 8 inches of fuel hose should be maintained between the filler neck and the fuel tank interface.
- Make certain that any added hose is suitable for the type of fuel used and meet OEM and federal standards.
- Provide a ground strap to ensure that electrical ground connection is made. Ground straps should be connected to brackets or flanges, not the fuel fill/vent system tubing. Ground straps should have a minimum of 10mm clearance, in all deflected positions, from any metallic portions of the fuel fill/vent system assembly.
- Alterations of fuel line routings could affect the completed vehicle and are not desirable. The complete fuel system must comply with FMVSS 301 as well as Federal and C.A.R.B. vapor emission requirements. Fuel Fill / Vent pipe hoses should be trimmed to hose retaining beads (when present); hoses should be secured with approved hose clamps at proper OEM torque specs. Fill pipe ends must be free of burrs.
- LPG Cutaway: The LPG fuel fill line must be attached to the underside of the Upfitter body as high as possible above the OEM frame and any longitudinal structural Upfit Body members.
- Pickup Box Removal & ZW9: Please refer to the Special Applications section of the Body Builders Manual for fuel filler zoning & routings, capless to capped fuel filler conversions & other guidelines.

Recommended Routing Method (zoned filler)



For additional information on Fuel Systems refer to the GM U.I. Body Builders Manual.

Fuel Systems (cont'd)

Fuel Line Modifications

When adding components near the fuel-line area, be sure to provide a minimum clearance of 305 mm (12 in.) to the exhaust system or install a protective metal shield. Use only GM-approved fuel line assembly suppliers and components.

CAUTION Replace damaged fuel lines. Never attempt to use or repair a fuel line that has been kinked.

General Motors also recommends the following precautions:

- Be careful not to bend fuel lines and avoid routing them near sharp edges and protruding objects. Clip fuel lines to chassis, spacing the clips every 600 mm or less. Metal clips should have plastic or rubber liners. (Figure 28)
- Use corrosion-resistant steel tubing with short sections of approved electrically conductive hose to connect components. Steel tube ends should be beaded for hose retention. Replace the entire tube at the new required length. Do not cut. (See Fuel Line Material specification UNSG10080/UNSG10100 Cold Rolled Steel, also identified as GM 124-M.)
- An in-tank pump pressurizes the fuel supply. Do not use coupled hose, nylon quick connects or clamped hose.
- Before adding extensions, clamp remaining fuel lines to prevent contamination during vehicle conversion (Figure 29).
- Avoid exposing fuel system components and lines to high temperatures such as those that may occur during welding. Doing so may cause system damage. After modification, use a fuel system prime tool to activate the fuel pump.

All engines require a fuel return system which returns excess fuel from the injection pump and injector nozzles back to fuel tanks.

All gasoline engine vehicles are equipped with fuel evaporative emission control equipment which is certified to be in compliance with the Federal or applicable California Vehicle Emission Standards. Alterations to fuel tank and metering unit, lines, canister or canisters, canister filters, canister purge control valves, relay switches, tank auxiliary vent valve, engine speed controller, or other devices/systems are therefore not allowable since vehicle adherence to C.A.R.B. and Federal regulations may be affected.

Diesel powered vehicles incorporate water drain provisions in the fuel system. These valves are only to be opened when removing water and contaminants from the fuel system.

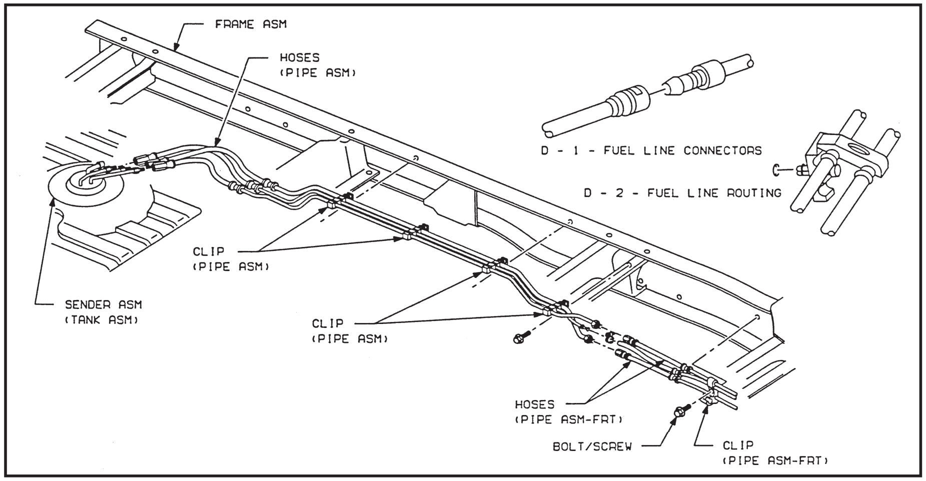


Figure 28

Fuel Systems (cont'd)

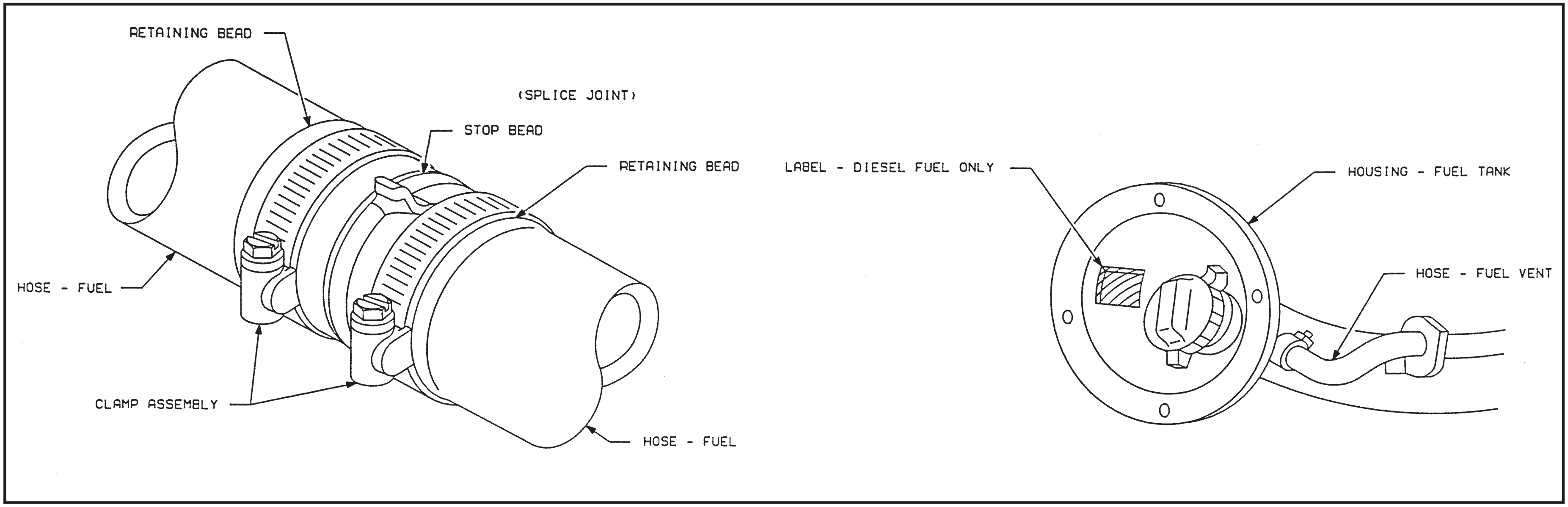

RETAINING BEAD
(SPLICE JOINT)
STOP BEAD
RETAINING BEAD
HOSE - FUEL
CLAMP ASSEMBLY
HOSE - FUEL
LABEL - DIESEL FUEL ONLY
HOUSING - FUEL TANK
HOSE - FUEL VENT

Figure 29

Fuel Tanks
After Upfit is complete fuel system must be fully functional. Do not modify or use non-OEM fuel tanks on ambulance vehicles. Use only specific OEM (not aftermarket) fuel caps. Provide minimum clearance of 51 mm (2 in.) between the fuel tank and the top, front, rear and sides of body and other supports.

Other recommendations are:
- Do not apply undercoating to fuel tanks.
- Make sure to point bolts, screws and other potentially damaging objects away from the fuel tank. Shield all such projections to help maintain fuel system integrity in the event of a vehicle crash.
- Diesel-powered vehicles incorporate a water drain provision in the fuel system. Do not open these valves, except to siphon water and contaminants from the fuel system.

Tank may be pressurized to 1.25 PSI maximum to check for final line leakage or for forcing fuel through the system. Pressures greater than this amount may be detrimental and affect tank durability.

Auxillary Fuel Tanks & Diesel Exhaust Fluid (DEF) System

Auxiliary Fuel Tanks & Generators

If an auxiliary fuel tank is added, the alterer is responsibile for compliance with affected motor vehicle safety and emission standards. Also, if an auxiliary fuel tank is added fuel must be drawn through a designated tap at the top of the tank (balance line between tanks is not permitted). Venting of auxiliary tank to be provided via purge canister and not to atmosphere. Vehicles are now equipped with a fuel pump return line. If an auxiliary tank is added, the tank selector valve must include a port which returns fuel to the tank from which the fuel is being drawn. Similarly, addition of another fuel line for a generator may require emission revalidation.

The battery must be disconnected before starting any work on the fuel system.

Diesel Exhaust Fluid (DEF) System

The Upfitter is responsible for any modifications to the DEF system.

Def Fill

- Locate Def Fill In Zones or areas outlined in Body Builders Manual.
- DEF fill location to always be above tank, gravity fed 4 degree angle (min.) with minimal bends.

Tank Placement

- Tank movement is not recommended.
- GM has validated the system durability only in the locations available for purchase.
- The existing DEF tank mounting hardware should not be altered.
- DEF tank/line surface temps cannot exceed 70C, proper shielding is required.
- DEF tanks do not have a drain. Service procedure must be followed if contaminated. (remove and drain).
- DEF Tank cannot be moved on full body vehicles (FMVSS301).

Def Fill Hose Assembly

- Increasing the hose length not recommended.
- Shorten from tank end is preferred.
- DEF fill line should be properly supported and secured

Fluid Delivery Line

- This line is heated, do not cut or adjust length.
- Carefully coil any extra line and secure to maintain the “as shipped” heated line length.

Wire Harness

- Do not change/modify the wire harnesses on the DEF tank.
- Carefully coil any extra line and secure.

Brakes

Brakes General Requirements

SVMs must ensure that the brake system functions properly after upfit is complete. Do not modify or alter the brake system. Frame alterations that require brake line modifications must comply with OEM & federal requirements.

Federal Standards and Regulations

Brake systems must conform to all federal motor vehicle safety standards and regulations, including:

- FMVSS/CMVSS 105: Hydraulic Service Brake Normal, Emergency and Parking Brake Performance
- FMVSS/CMVSS 106: Brake Hoses — Hydraulic, Air and Vacuum
- FMVSS/CMVSS 116: Motor Vehicle Brake Fluids
  For additional information, refer to the following SAE specifications:
- SAE J1401: Road Vehicle — Hydraulic Brake Hose Assembly Use with Non-Petroleum Base Hydraulic Fluids
- SAE J1288: Packaging, Storage and Shelf Life of Hydraulic Brake Hose Assemblies
- SAE J1403: Vacuum Brake Hose
- SAE J1406: Application of Hydraulic Brake Hose to Motor Vehicles

Modification Checklist

For vehicle-specific diagnostic, inspection and service guidelines, refer to the appropriate GM Service Manual. The following checklist will also help SVMs to ensure proper brake system operation after frame alterations.

- Do not splice the park-brake cable.
- Make sure the hydraulic brake system is free of air and hydraulic leaks. Bleed brakes if necessary.
- Ensure that the vacuum booster system or hydroboost system is functional and free of leaks.
- Check the master cylinder fluid level. Fill as necessary.
- Check the power steering fluid level on vehicles equipped with hydroboost brake.
- Make sure that added floor carpeting does not restrict service or parking brake pedal travel.
- Provide at least 51 mm (2 in.) clearance between body- or chassis-mounted components and brake hoses.
- Never change the brake main cylinder location, brake pedal pushrod length or pedal position.
- Verify that the brake warning switch is operative.
- Do not add suspension accessories or make any modification that will change axle loads or trim height. Such changes may provide a false reading to the brake proportioning valve.
- Vehicle weight, weight distribution and center of gravity determine the appropriate proportioning valve.

Brakes (cont'd)

Brake Lines

Cover all brake line extensions with a protective coating to prevent corrosion (use GM specification 123m or equivalent). Construct brake line extensions of steel tubing capable of withstanding operating pressure of at least 2,500 PSI.

Route brake lines along inner frame sections, being careful to avoid sharp edges, protruding objects and short bends. There must be no evidence of brake line twist.

Allow at least 17 mm (0.7 in.) clearance between brake lines and moving components, and at least 13 mm (0.5 in.) between brake lines and vibrating components. Clip brake lines at least every 762 mm (30 in.). Figure 30 shows proper brake-line routing and fastening.

CAUTION Do not repair kinked or cracked brake lines. Replace all damaged lines with new brake lines.

CAUTION Do not splice brake lines. Replace entire brake line at new required length.

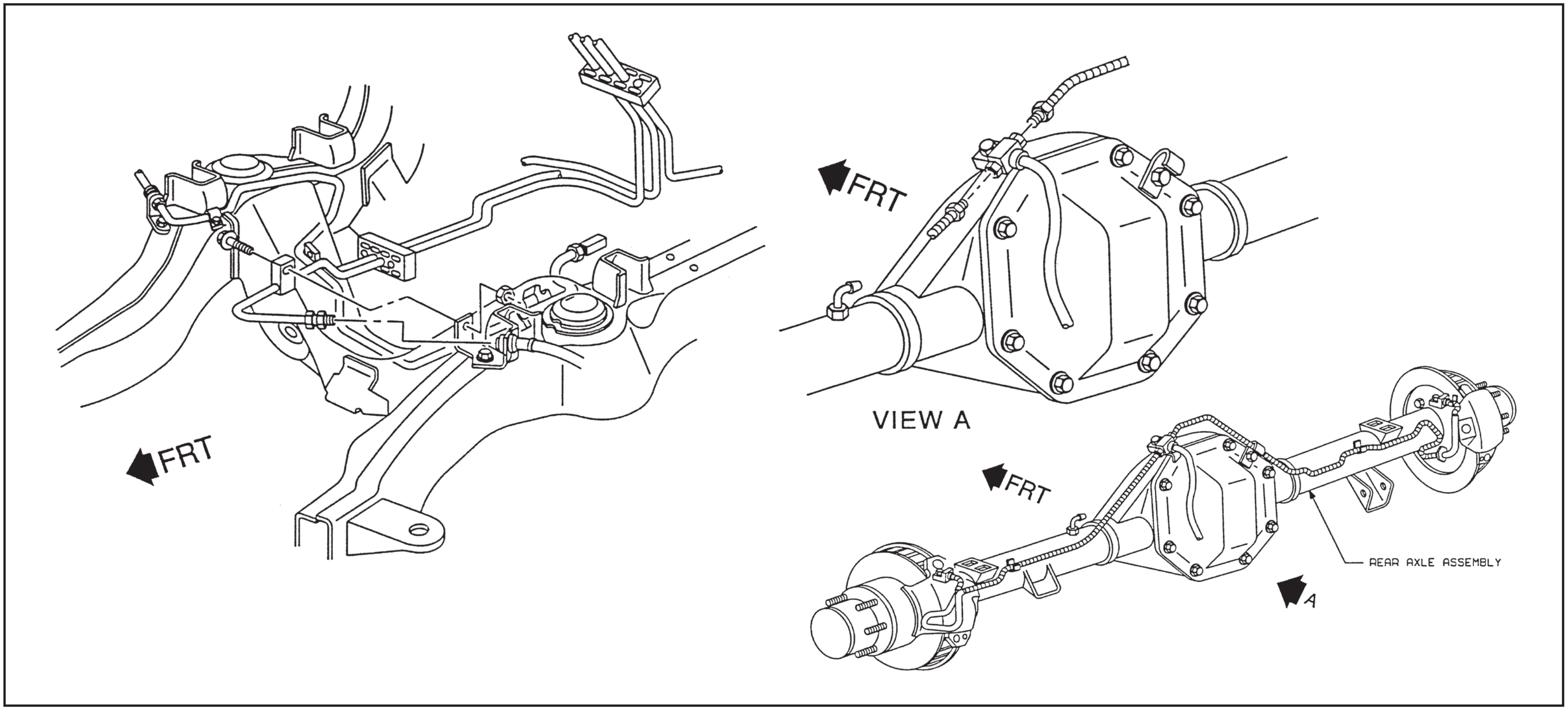


Figure 30

Brakes (cont'd)

Parking Brake Systems

If so equipped, the vehicle's mechanical parking brake system with automatic vacuum release consists of parking brake pedal assembly, vacuum diaphragm, cables and connectors (Figure 31). The parking brake system should be able to withstand at least 400 lbs. of cable tension. General Motors recommends using a one-piece parking brake cable assembly consistent with the base vehicle. For adjustment and testing procedures following installation, refer to the appropriate GM Service Manual.

! Avoid special vehicle designs (e.g., ground-effects packages) that may prevent proper brake system ventilation. Lack of ventilation may lead to shortened brake life.

Additional recommendations are:

- Allow at least 17 mm (0.7 in.) clearance between brake lines and moving components (e.g., steering shaft, shift levers, etc.).
- Allow 13 mm (0.5 in.) clearance between brake pipes and vibrating parts (e.g., front sheet metal, underbody and power brake booster) unless pipes are clipped to these components.
- Use brake line clips spaced at intervals no greater than 762 mm (30 in.).

CAUTION Do not splice parking brake cable. Replace with new cable at required length only.

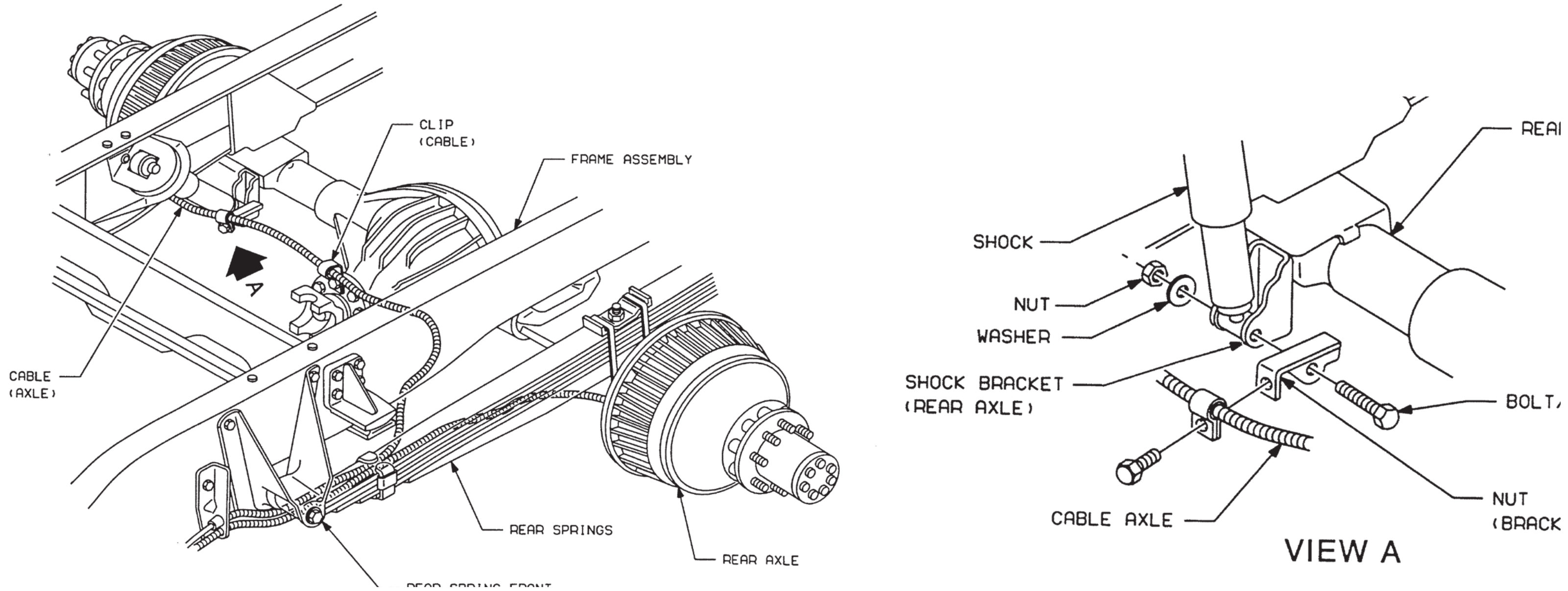


Figure 31

Brakes (cont'd)

Electronic Dynamic Rear Proportioning (DRP)

Electronic Dynamic Rear Proportioning (DRP) allows better utilization of the rear brakes, which reduces brake wear. Moreover, this better balancing of the brake system as a whole improves brake performance.

Benefits include:

- Good balance with front brakes when truck is heavily loaded or under towing/trailering conditions
- Provides maximum braking forces at rear wheels
- Provides maximum braking forces when braking on an uneven road surface, such as a washboard at an intersection
- Reduced front brake wear
- Better use of rear brakes
- Improved braking performance

Since changes in vehicle mass, mass distribution, and center of gravity determine the appropriate proportioning, the altered vehicle must not exceed GVWR, front and rear GAWR, and stay within the allowable center of gravity range.

Exhaust System

SVMs must be careful to use components and follow procedures that will prevent exhaust fumes from entering any occupant area. Observe the following guidelines:

- Seal all holes and openings through the floor and body.
- Make sure exhaust discharge is unobstructed and directed away from passenger areas.
- With the vehicle in motion, test the tailpipe outlet location to ensure that fumes do not enter the passenger compartment.

! Altering the exhaust outlet or its position, and removal or alteration of noise abatement components may place the vehicle in violation of federal, state or local noise laws. The SVM may have to recertify vehicle compliance with federal, state and local noise emission requirements.

The SVM must assume full responsibility for complying with Environmental Protection Agency (EPA) noise regulations if the exhaust system is modified.

The U.S. Environmental Protection Agency (EPA) has established noise emission standards applicable to vehicles (in general vehicles in excess of 10,000 pounds GVWR capable of transportation of property on a street or highway) manufactured after January 1, 1978, under the provisions of the Noise Control Act of 1972. The standards provide that vehicles manufactured after January 1, 1978, when tested pursuant to EPA's prescribed test procedure, must conform to an 83 dBA level and vehicles manufactured after January 1, 1988 must conform to an 80 dBA level.

The Act and the standards impose legal obligations on vehicle manufacturers and subsequent manufacturers.

The standards or interpretations of such standards are subject to change by the EPA. New standards or amendments issued by the Environmental Protection Agency appear in the Federal Register. You may obtain the Federal Register through the Superintendent of Documents, U.S. Government Building Office, Washington, D.C. 20402.

Various state and local requirements regulate vehicles above and below 10k GVWR. For specific rules, test procedures and permissible noise levels, refer to specific state regulations.

! Exhaust pipe modifications must comply with recently enacted federal EPA regulations regarding exhaust system leaks. (Refer to federal regulations for additional information.

Exhaust System — Noise & Emissions

Component content certified to meet all required standards. Can not be modified.

Exhaust System — Tail Pipe Modifications

When designing specialty vehicle exhaust systems, SVMs should observe the general recommendations listed below.

- Make sure that the design maintains:
  - — proper design and spacing of the OEM hanger bracket
  - — sufficient clearance for thermal expansion of materials
- Use only aluminized 409 stainless steel or aluminized mild steel to lengthen exhaust pipes.
- To avoid excessive exhaust back pressure and resultant loss of engine power, make sure the exhaust pipe has
- OEM tailpipe tips must be present on modified diesel exhaust pipes.

Exhaust System (cont'd)

Exhaust System Design (cont'd)

- Under extreme operating conditions, exhaust temperatures can exceed 1,600ºF, with slightly lower pipe surface temperatures. When adding body components and mud flaps near the exhaust system, be extremely careful to choose components with the appropriate temperature ratings, or provide shielding.
- The exhaust system rotates with the engine. This requires a minimum clearance of 17 mm (0.7 in.) from the floorpan and frame (Figure 32).
- When conversion is complete, check for leaks and restrictions in the exhaust system (Figure 32). Repair as required.

For additional information on exhaust pipe installation, refer to the GM Body Builders Manual.

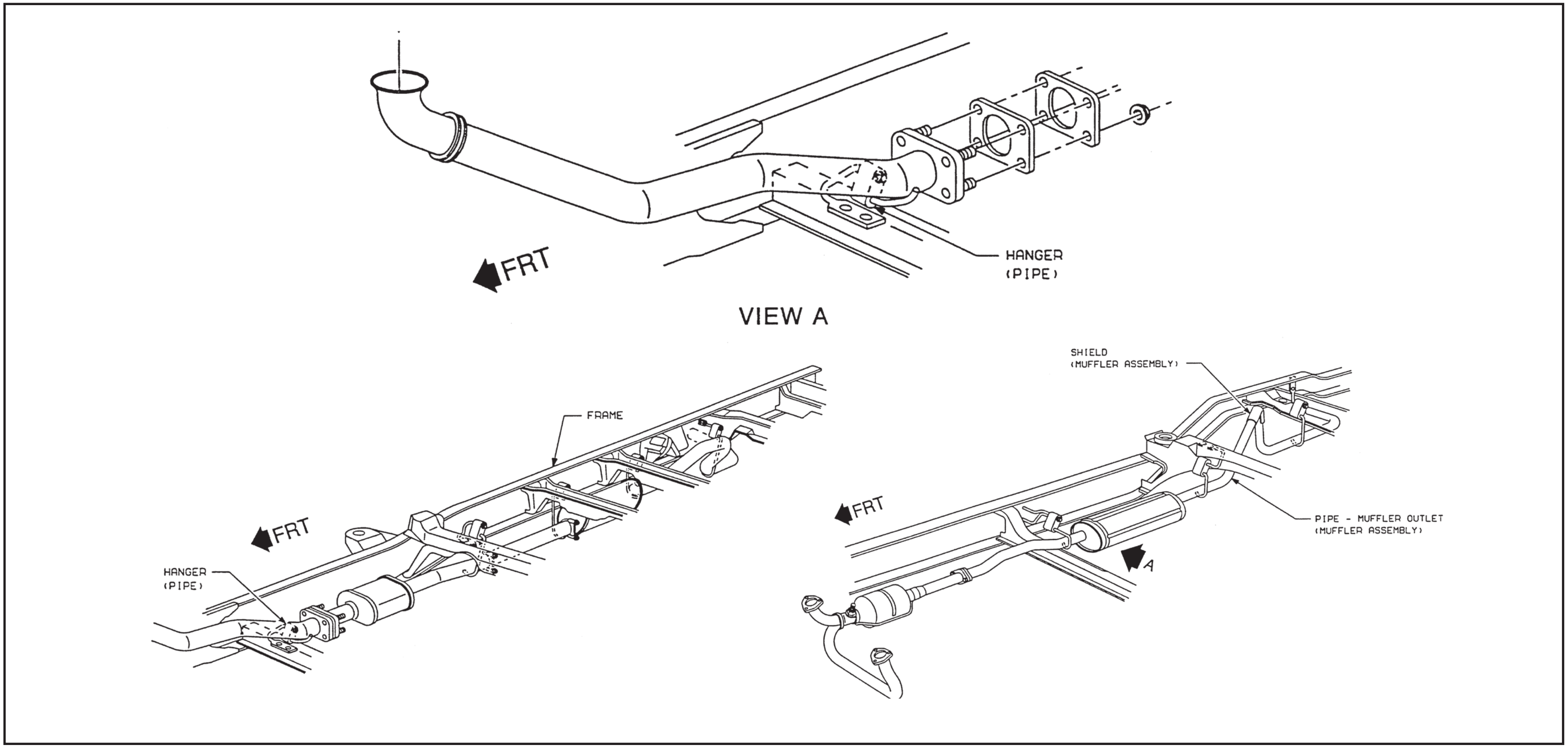

FRT
HANGER (PIPE)
VIEW A
FRAME
FRT
HANGER (PIPE)
SHIELD (MUFFLER ASSEMBLY)
FRT
PIPE - MUFFLER OUTLET (MUFFLER ASSEMBLY)
A

Figure 32

Exhaust System (cont'd)

Routing

When determining exhaust routing locations, be sure to consider the thermal expansion of the extension area. Additional guidelines are:

- Tailpipe extensions must extend at least 51 mm (2 in.) outboard of the body side panels.
- Added exhaust hangers should allow expansion without binding up.
- Do not locate tailpipe exit forward of the rear wheels. Ensure exhaust gases do not enter the passenger compartment through side or rear windows, or underbody seams and holes.
- Weld all connections when adding extensions to existing exhaust systems. Use GM-approved sealers at all slip-joint connections except at the catalytic converter.

CAUTION Do not route electrical wires, fuel lines or HVAC hoses over the exhaust system.

Shielding

Heat shields are necessary in areas where high exhaust temperatures will affect vehicle component performance. Heat shields should be made of aluminized steel with a minimum 0.9 mm (0.035 in.) thickness.

CAUTION Do not alter or remove any heat or grass shields from the OEM exhaust system.

Also provide similar shielding to any exhaust component extension. If exhaust pipes are extended rearward directly past the spare tire, install shielding to protect the tire.

Mount heat shields to the underbody and/or exhaust system components (catalytic converter and muffler).

Some vehicles may also require shields for the propshaft hanger bearings.

Undercoating

Do not apply undercoating to:

- Any part of the exhaust system
- Any component within 300 mm (11.8 in.) of the exhaust system

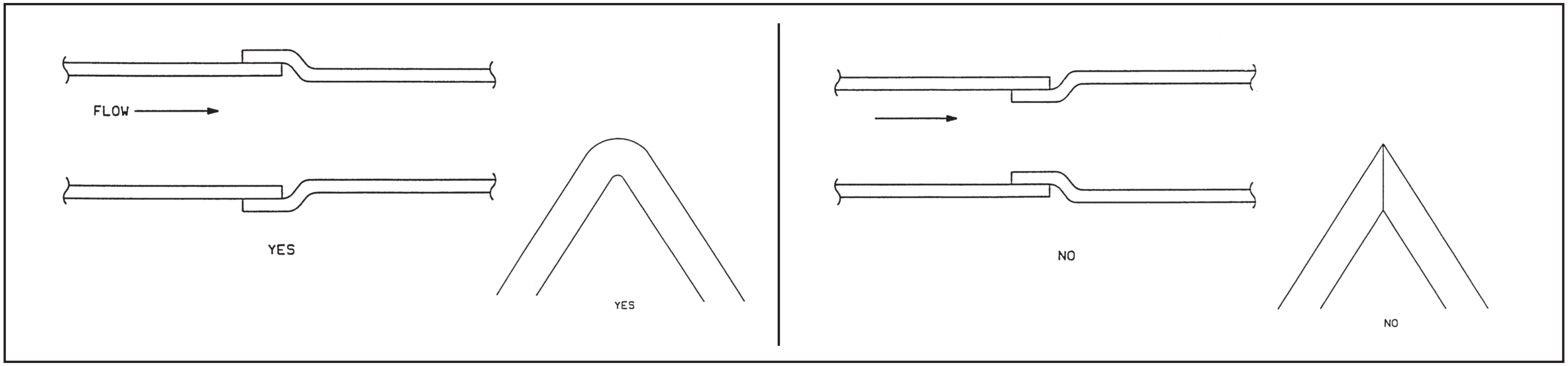


Figure 32

Suspension System

Suspension System General Requirements

SVMs should adhere to the following recommendations:

- Do not weld to any axle assembly.
- Design body and equipment arrangements that allow proper load distribution on both front and rear axles.
- Use designs that consider and maintain lateral load equalization.
- Make sure that the unladen vehicle's center of gravity (after conversion) falls within the limits specified in the FMVSS 105 section of the "Incomplete Vehicle Document".
- Do not route pipes, wiring or related components in suspension component paths of motion. These components include rear axle, springs, shocks, brake pipes and hoses.

CAUTION Do not alter suspension design geometry. Any modifications to suspension design or geometry could result in Upfitter voiding GM Warranty and assuming liability for the modification.

Front Suspension

- Since there is a large variation in completed vehicle front weight due to differences in body weight and equipment, the front suspension alignment must be checked and reset after the vehicle is completed. Caster and camber should be set with reference to the "Z" and "D" as built trim height dimensions. On C3500 HD trucks with I-beams, camber and caster are designed into the axle/suspension and cannot be adjusted.
- See the Service Manual for complete alignment procedure, specifications and measurement of the "Z" and "D" as built trim height dimensions under the "Diagnosis and Wheel Alignment" sections.
- C/K Models are designed so that camber and caster do not need adjustment unless severe road impact or accident deformation occurs. Toe should be reset after the vehicle is completed and while at normal operating load with trim height as specified.

Rear Suspension

Clearance

- Provide clearance to the body for the suspension, axle, and tires under the following conditions:
  - — Axle in full jounce against the metal-to-metal stop
  - — Axle at 4.5-degree roll
  - — Axle at design position
  - — Axle in full rebound
- Allow the following clearance for tire chains:
  - — Design for maximum growth tire.
  - — Allow 42 mm (1.66 in.) to sides of tire.
  - — Allow 64 mm (2.5 in.) to top of tire.
  - — Customer notification may be required in some states if chains cannot be used.
- Refer to the GM Body Builders Manual (C/K section) for additional information on clearance to body/chassis and rear suspension.
- Pipes, wiring, conduits and any other related components must not be placed where they cross the path of motion of the rear axle, driveshaft, axle brake pipes, hoses, spring or tires. Such crossing could result in rupture, wear-through, or separation due to normal axle motion.

Wheels And Tires

Since May, 1971, National Highway Traffic Administration regulations have required manufacturers to maintain specific information on tires.

In compliance with these regulations, General Motors keeps records on tires installed on each vehicle it ships. It is important for the SVM to ship the vehicle with OEM tires. Any tire removed from the vehicle during conversion should be replaced.

The SVM is responsible for keeping records on any tire changes made during conversion. All data must correspond to the correct vehicle identification number (VIN). For specific information, refer to Federal Regulation 574.

All tires must meet FMVSS 120 (CMVSS 120) new tire and rim selection regulations. Factory-installed OEM tires and wheels are designed to operate up to full load capacity when tires are inflated to specification.

CAUTION GM recommends not altering OEM offered tire/wheel design combinations or tire pressures. Under or oversize tire/wheel combinations could result in Upfitter voiding GM Warranty and assuming liability for the modifications.

Other recommendations are:

- GM recognizes wheel exceptions for Hyrail Upfits.*
- Use only the OEM wheels on any ambulance vehicle.
- The OEM lug nut bearing surface should not retain any wheel trim such as wheel simulators.
- Check wheel lug nuts for proper torque. For torque specifications, see the Owner Guide.
- Check tires and inflate to recommended tire pressure. Refer to either the vehicle's tire inflation label or the Owner Guide.

For wheel maintenance guidelines, refer to the appropriate GM Service Manual.

* For guidance with Hyrail Upfits contact GM Upfitter Integration.

Contents

Scope 9

Common Electrical Problems 10

GENERAL INFORMATION 10

FAILURE MODES 10

Short Circuit 10

Open Circuit 10

Intermittent Circuit 11

Sources of Electrical Problems 12

OEM and Auxiliary Battery Guidelines 17

OEM BATTERY GUIDELINES 17

General Information 17

Discharge Prevention 18

Charging Procedures 19

OEM BATTERY RELOCATION GUIDELINES 20

Location 20

Vibration: 20

Accessibility 20

Tilt Angles 21

Temperature 21

AUXILIARY BATTERY GUIDELINES 21

General Information 21

Location 21

Venting 22

Mounting and Fastening 22

Connecting and Grounding 22

    - Cable Sizing......22
    - BATTERY DISCHARGE LIMITER GUIDELINES......23
- Electrical System Interfacing – New Circuit Guidelines......25
    - NEW CIRCUIT GUIDELINES......25
    - Interfacing to the OEM Electrical System......25
    - Body Builder Junction Block/Connector......26
    - EXTENDING OEM CIRCUIT GUIDELINES......26
- Electrical System Interfacing – Design Guidelines......28
  - Design Guidelines......28
    - Cable (Wire) Selection Guidelines......28
    - Cable Ampacity......28
    - Design Recommendations......28
  - Cable (Wire) Types......29
    - • Passenger compartment......29
    - • Engine compartment......29
    - Typical Calculation Example......32
  - WIRE HARNESS ASSEMBLY GUIDELINES......33
    - Design Recommendations......33
  - CONNECTING GUIDELINES......33
    - Design Recommendations......33
  - CONNECTOR TYPES......35
    - Unsealed Connectors......35
    - Sealed Connectors......35
  - HOW TO CHOOSE A CONNECTION SYSTEM......36
    - Terminals......36

- Terminal Characteristics 37
- ASSEMBLING CONNECTION SYSTEMS 39
- Terminating a Wire (Hand Crimped) 39

SOLDERING GUIDELINES 42

- Soldering Procedures 42
- Seating Terminals 43
- Adding secondary or TPA locks 44
- Hinged Secondary Locks 45
- MATING TWO CONNECTORS TOGETHER 45

DISASSEMBLING CONNECTION SYSTEMS 46

- Removing TPA or Secondary Locks 46
- TERMINAL REMOVAL 47

Splicing Guidelines 48

- Splicing Two Wires 48
- Splicing Multiple Wires 51
- Recommended splicing procedure: 51

Soldering the Splice Clip 52

- Choosing a Splice Clip 53

WIRE HARNESS COVERING GUIDELINES 54

- Wire Coverings 54
- Selecting Convoluted Conduit: 56
- When Should Circuit Protection Be Used? 58
- Circuit Protection Design Recommendations 59

ELECTRICAL COMPONENT GUIDELINES 60

- Ratings 60

    - Component Tolerance Levels 61
    - Component Handling 61
  - Component Precautions 62
  - RADIO FREQUENCY INTERFERENCE (RFI) PREVENTION 62
  - SERVICEABILITY 63
    - Design Parameters 63
    - Diagnosability 64
    - Accessibility 64
    - Repairability/Replaceability 64
    - Limited-Life Components 64
  - FMVSS/CMVSS REQUIREMENTS 64
    - FMVSS/CMVSS 108: Lamps, Reflective Devices and Associated Equipment 65
    - FMVSS/CMVSS 118: Power Operated Window Systems 65
- Electrical System – Installation Guidelines 66
  - WIRE HANDLING GUIDELINES 66
  - WIRE ROUTING GUIDELINES 66
    - Location 67
    - Tension 67
    - Accessibility 68
    - Appearance 68
  - WIRE FASTENING GUIDELINES 68
    - Additional recommendations are: 68
  - WIRE AND ELECTRICAL COMPONENT PROTECTION GUIDELINES 69
    - Protective Devices 69
    - GROUNDING GUIDELINES 70

ISOLATION OF “CLEAN” AND “DIRTY” ELECTRICAL GROUNDS 70
Clean Grounds 71
Dirty Grounds 71
WELD NUTS, WELD STUDS, SCREW/WASHERS AND TERMINALS USED FOR GROUNDING 71
Weld Nuts 71
Weld Studs 72
Electrical System – OEM Components 73
OEM COMPONENT LOCATION GUIDELINES 73
Safety Systems: 73
Electrical Components (non-safety system related) 73
Under-hood/Vehicle: 73
Under-dash: 73
Doors: 73
Under Seats: 74
Rear Stowage Areas: 74
General Recommendation: 74
Repairing Damaged Wire Insulation 75
Splicing Inline Harness Diodes 76
Splicing Twisted or Shielded Cable 77
Wire to Wire Repair 79
Splice Sleeve Selection 80
Weatherpack™ Wiring Repair 84
Connector Position Assurance Locks 86
Terminal Position Assurance Lock 86
CPA Connectors 86

        - Connector Installation Procedure 87
- Delphi Connectors (Weather Pack®) 88
  - Terminal Removal Procedure 88
- Delphi Connectors (Push To Seat) 90
  - Terminal Removal Procedure 90
  - Terminal Insertion Procedure 91
- Delphi Connectors (Pull To Seat) 92
  - Terminal Removal Procedure 92
  - Terminal Insertion Procedure 92
- Delphi Connectors (Steering Gear) 93
  - Removal Procedure 93
- Yazaki Connectors (2-Way) 94
  - Terminal Removal Procedure 94
- Yazaki Connectors (16-Way) 95
  - Terminal Removal Procedure 95
- Repairing Connector Terminals (Terminated Lead Repair) 98
- Repairing Connector Terminals (Terminal Repair) 98
  - CABLE SEAL TERMINALS 98
  - UNSEALED TERMINALS 99
- Terminal Removal 99
- Relay Replacement (Attached to Wire Harness) 101
  - Removal Procedure 101
  - Installation Procedure 101
- Relay Replacement (Within an Electrical Center) 102
  - Removal Procedure 102
  - Installation Procedure 103
- Ground Repair 104

ELECTRICAL GROUNDS ... 104
  M6 Weld Stud Replacement ... 104
  M6 Weld Nut ... 105
  M6 Weld Nut (Alternative Repair) ... 106
  M8 Weld Nut ... 107
  M8 Weld Nut (Alternative Repair) ... 108
Securing Loose Electrical Ground Connections ... 109
Electrical System – Customer Convenience ... 110
CUSTOMER CONVENIENCE ... 110
FUNCTION MARKING ... 110
LOCATION IDENTIFICATION ... 110
INSTRUCTIONS ... 110
DOCUMENTATION ... 110
Electrical System – Headlamp/Fog lamp Guidelines ... 112
HEADLAMP AIMING ... 112
Electrical System – SIR Precautions ... 113
Precautions ... 113
SIR Disabling and Enabling ... 113
Electrical System – SIR Disabling and Enabling ... 114
SIR Identification Views ... 114
General Service Instructions ... 115
Disabling Procedure - Air Bag Fuse ... 115
Enabling Procedure - Air Bag Fuse ... 115
Disabling Procedure - Negative Battery Cable ... 116
Electrical System – SIR Disabling and Enabling (continued) ... 116
Enabling Procedure - Negative Battery Cable ... 116
Electrical System – Welding High and Voltage Precautions ... 117

Welding Precautions 117
High Voltage Precaution 117
Electrical System – Appendix 1 118
Achronym or Term Chart 118
UNITS DEFINITIONS 137
Electrical System – Appendix II – Connecting Terminology 138
CONNECTING TERMINOLOGY 138
Connection system 138
Connector 138
Indexing feature 138
Inertia lock 139
Cavities 139
Terminal 139
Core wing 139
Insulation wing 139
Locking tang 139
Secondary lock or TPA lock 139
CPA lock 140
Cable seal 140
Electrical System – Appendix II – Fuses 141
ATO FUSE Characteristics 141
MAXI FUSE Characteristics 141
Electrical System – Appendix II – Available Tools 142
CRIMPING TOOLS 142
OTHER TOOLS 142
TERMINAL REMOVAL TOOL 143
STANDARD TERMINAL REMOVAL TOOL 143
Miscellaneous Tools 144

Scope

The scope of this Electrical Manual is to define General Motors recommendations for the design and installation of non-OEM (Original Equipment Manufacturer) low-voltage electrical systems and components in GM vehicles by personnel engaged in the conversion of automotive vehicles. Also included in this manual are guidelines for the interfacing of Upfitter installed electrical systems to the General Motors OEM electrical system. This is not a "how to" manual. It assumes the reader has technical expertise in the area. Ultimate responsibility for all work rests with the Upfitters.

Common Electrical Problems

GENERAL INFORMATION

This section describes several common automotive electrical problems and failure modes. General Motors recommends that Upfitters become familiar with these common problems. Doing so will help to avoid potential failure and other serious problems in the vehicle's electrical system and components.

FAILURE MODES

Short Circuit

A short circuit is a connection of comparatively low resistance, made either accidentally or intentionally, between two points in an electrical circuit. In other words, a short circuit is a direct connection between two circuits. Typically, when a power circuit shorts to a grounded circuit or conductive metal in the vehicle, it causes a circuit protection device (CPD) to open and protect the wiring from damage. However, it is possible for a short circuit to cause damage to the wiring and to the vehicle. This occurs if a circuit is not properly protected. The tremendous amount of current that flows through a wire, generated by a short, causes the wire to heat up, melt the insulation around the wire and adjacent wires, and may even lead to a thermal event. Damage to a vehicle resulting from a short circuit can be avoided with proper fusing. Therefore, it is very important to follow good circuit protection guidelines any time a new circuit is added to a vehicle electrical system. A short circuit may result when a cut, pinched or chafed wire makes contact with a grounded component of the vehicle.

Open Circuit

An open circuit is a circuit that has lost contact in a way that prohibits the flow of current. This condition creates infinite resistance between two circuits and usually results in the malfunctioning of an electrical component. An open circuit may result from:

- A pinched or cut wire
- Improperly seated terminal(s) in a connector
- A poor or improper terminal crimp
- Corroded terminal(s)
- Improperly connected ring terminal

Intermittent Circuit

An intermittent circuit is a circuit that repeatedly opens or shorts temporarily. In other words, the circuit makes and breaks contact over and over again. It may be caused by:

- A pinched wire
- A loose ring terminal
- Improper seating of terminal(s) in a connector
- Incomplete mating of connectors
- Corroded terminals

Sources of Electrical Problems

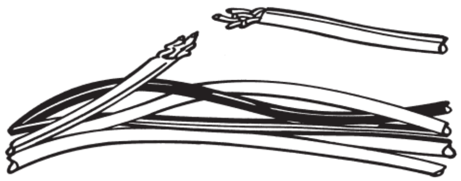
A variety of conditions can cause problems with the automotive electrical system and its components.

These include:

- Cut, broken, pinched or chafed wire
- Burned wiring or melted insulation
- Loose or unconnected ring terminal
- Terminal core grip wings crimped over wire insulation
- Un-crimped terminal core grip wings
- Terminal backed out of connector
- Bent or damaged terminal in connector
- Corroded terminal
- Partially or completely disconnected connector
- Poor or missing ground
- Crossed wire in connector
- Missing wire
- Misrouted wire
- Short wire lead(s)
- Damaged connector
- Improperly installed light bulb
- Disconnected light bulb socket

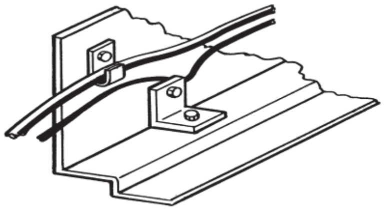
Common Electrical Problems (continued

CUT OR BROKEN WIRE – May result in a temporary short as cutting occurs and then an open circuit.



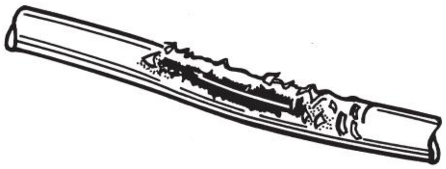
Electrical Problem Example #1

PINCHED WIRE – Wire pinched between two objects such as brackets. Will usually result in a short circuit due to cold flow of insulation material.



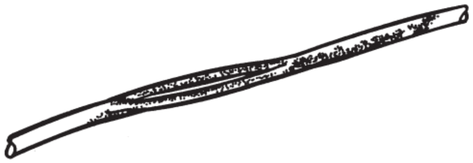
Electrical Problem Example #2

CHAFED WIRE – Wire insulation has been rubbed away exposing the wire core. Will usually result in a short circuit.



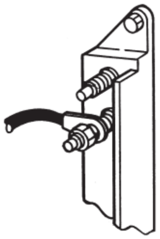
Electrical Problem Example #3

BURNED WIRE OR MELTED **INSULATION** – Wire located too close to a radiant heat source. Insulation will be discolored and melted, possibly exposing wire core, which will usually result in a short circuit.



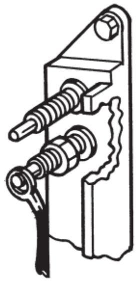
Electrical Problem Example #4

LOOSE RING TERMINAL – Bolt, screw, or nut used to secure the terminal is not completely tightened. Can result in arcing and/or an intermittent or open circuit.



Electrical Problem Example #5

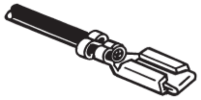
UNCONNECTED RING TERMINAL – Terminal is not secured at all with a bolt, screw or nut. Will result in an open circuit.



Electrical Problem Example #6

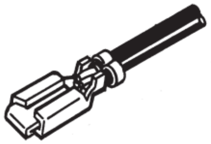
Common Electrical Problems (continued)

TERMINAL CORE GRIP WINGS CRIMPED OVER WIRE INSULATION – Terminal has no contact with the wire core due to insulation not being properly removed or positioned. Results in an open circuit.



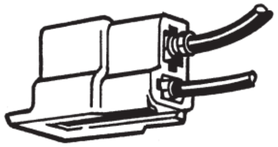
Electrical Problem Example #7

TERMINAL CORE GRIP WINGS NOT CRIMPED – Terminal has not been secured to the wire core resulting in an intermittent or open circuit.



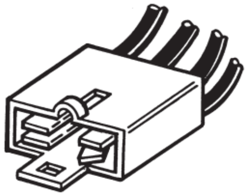
Electrical Problem Example #8

TERMINAL BACKED OUT OF CONNECTOR – Terminal has not stayed properly positioned inside the connector. As it “backs out” an intermittent or open circuit may result.



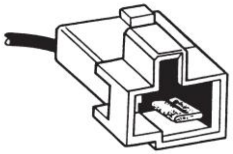
Electrical Problem Example #9

BENT OR DAMAGED TERMINAL IN CONNECTOR – May result in an intermittent or open circuit. A short circuit may occur if the bending causes two terminals to touch.



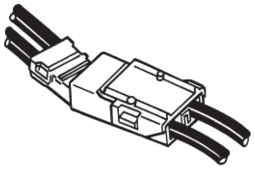
Electrical Problem Example #10

CORRODED TERMINAL – Corroding is evident when a greenish-white powder appears on the terminal. May result in high temperature in the connector or an open circuit due to high resistance.



Electrical Problem Example #11

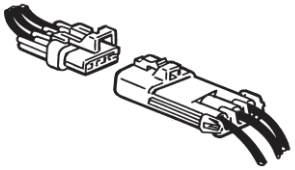
CONNECTOR PARTIALLY CONNECTED – “Partially” indicates that some terminals in a connector are making contact while others are intermittent or open circuit across the connection.



Electrical Problem Example #12

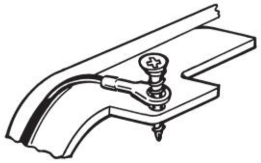
Common Electrical Problems (continued)

CONNECTOR COMPLETELY DISCONNECTED – The connector is not mated at all and all terminals are open circuit across the connection.



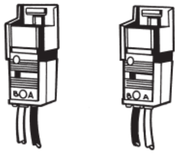
Electrical Problem #13

POOR OR MISSING GROUND – Ground terminal not fastened or only partially fastened to the body sheet metal. Can result in an intermittent or open circuit.



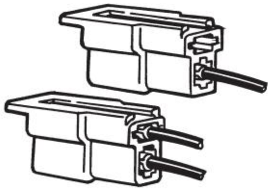
Electrical Problem #14

CROSSED WIRE IN CONNECTOR – Wire has been inserted into the wrong cavity in the connector during initial assembly or previous repair. May result in a malfunction of the circuit which could lead to a short circuit.



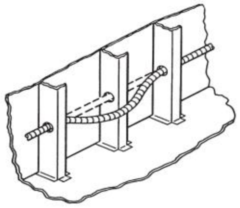
Electrical Problem #15

MISSING WIRE – May have been omitted during initial manufacturing of the harness assembly or left out during vehicle build.



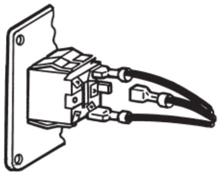
Electrical Problem # 16

MIS-ROUTED WIRE – Wire has been positioned incorrectly during vehicle build. Will usually result in one or more of the listed example problems occurring.



Electrical Problem #17

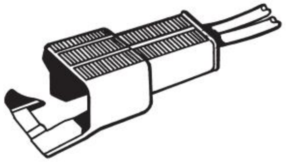
SHORT WIRE LEAD(S) – Wire may have been assembled improperly by harness manufacturer or might have been misrouted during assembly.



Electrical Problem #18

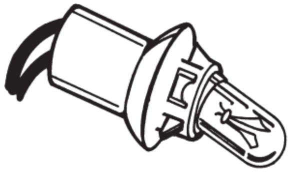
Common Electrical Problems (continued)

DAMAGED CONNECTOR – The connector is cracked, broken or melted. Will generally not mate properly and can result in an open or intermittent circuit.



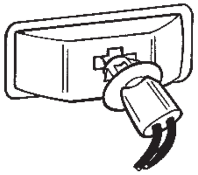
Electrical Problem # 19

IMPROPERLY INSTALLED LIGHT BULB – The bulb is not making proper contact in the socket and may flicker or not light at all.



Electrical Problem # 20

DISCONNECTED LIGHT BULB SOCKET – The bulb will light but the socket has come loose from the lamp housing and the lamp will not illuminate properly.



Electrical Problem #21

OEM and Auxiliary Battery Guidelines

OEM BATTERY GUIDELINES

The information in this section will help the Upfitter to prevent OEM battery discharge when upfitting GM vehicles. It is the Upfitter's responsibility to make sure that the OEM battery is at the same or higher state of charge when the completed vehicle is shipped, than what it was when the vehicle was received. Additionally, integration of Upfitter equipment with the vehicle electrical system should be done with the aim of protecting the battery from excessive discharge with the ignition off.

General Information

General Motors Light and Medium Duty Trucks are equipped with maintenance-free, sealed batteries that are designed to perform three major functions:

- Provide a source of electrical energy for cranking the engine
- Act as a voltage stabilizer for the vehicle electrical system
- Provide added energy when the vehicle's electrical load requirements exceed the output of the generator.

When connecting directly to the OEM battery, use only OEM approved connecting devices. Contact the Upfitter Integration group for approved components.

> CAUTION Upfitter provided battery bolts, which incorporate a threaded stud for direct attachment to the battery, should comply with OEM requirements for configuration, length, material, and terminal interface requirements. Failure to do so could compromise the vehicle electrical system performance, reduce battery life and physically damage the battery.
>
> CAUTION Battery bolts should be torqued to 17.0 ± 3.0 Nm. Do not over-torque as this could damage the battery.
>
> CAUTION Terminal attaching nuts, which are installed on Upfitter battery bolt/studs, should always be torqued to a specification that is lower than the installation torque requirement for the battery bolt itself, to prevent battery bolt over-torqueing.

Some electrical devices may impose a "parasitic" load on the OEM battery. Upfitters should not install this type of device in a GM vehicle.

Whenever practical and customer convenient, wire non-OEM electrical devices so that they are controlled by the vehicle's ignition system. This will prevent battery discharge if the electrical device is inadvertently left on. (**Note:** See the "Interfacing to the OEM Electrical System" section for recommended connection methods to the OEM ignition circuit.) Upfitter electrical devices that have a parasitic current draw should not be added to the vehicle.

** Refer to the appropriate GM service manual for specific information on battery usage, diagnosis and on-vehicle service procedures.

OEM and Auxiliary Battery Guidelines (continued)

Discharge Prevention

General Motors recommends that Upfitters implement practices that will prevent battery discharge that otherwise may occur during the conversion process.

- When storing a vehicle for more than 10 days (either before or after the conversion process), disconnect all negative battery terminals.

Some electronic devices, such as the radio, engine control module (ECM), powertrain control module (PCM), and the vehicle control module (VCM), impose small, continuous current drains on the battery. These are commonly called parasitic loads. If the vehicle is stored for an extended period of time, parasitic loads can deeply discharge the battery. Allowing it to stand in a deeply discharged state for long periods of time can permanently damage the battery.

⚠ Discharged batteries can freeze at temperatures as high as 20 degrees Fahrenheit, causing permanent damage. Never charge a frozen battery.

- Periodically (every 30-45 days) recharge the battery of any vehicle that has been stored for 30 days or more. The negative (ground) cable should be disconnected after each recharging.
- Always turn the ignition off before connecting or disconnecting battery cables. Failure to do so may damage the various control modules, the radio or other electronic components.
- Do not start the engine to move the vehicle from one assembly station to another within the same building. This discharges the battery and can foul the spark plugs. GM recommends moving the vehicle by some other method, such as pushing by hand.
- Never leave the vehicle ignition switch in the “ON” position if the engine is not running.
- Do not play the vehicle’s radio, TV, DVD player or other electrical equipment during the conversion process unless required for proper vehicle processing (e.g., testing the operation of such components).
- Do not leave vehicle hood and doors open during non-work periods (overnight, work breaks, shift changes, extended downtimes, etc.) if underhood or interior lights have not been disconnected. All electrical current-drawing devices should also be turned off during these periods.
- Some vehicles are equipped with an interior light override switch located on the instrument panel. Keep this switch in the “OFF” position and switch to the “ON” or “DOOR” position only as needed to energize the interior light circuit for checking purposes. (Note: Keeping this switch in the “OFF” position nullifies the need for keeping the vehicle doors closed.).

OEM and Auxiliary Battery Guidelines (continued)

- All Upfitter-added electrical devices should be installed in the “OFF” position and all Upfitter electrical checks performed during the assembly operation should require that the device be left in the “OFF” position. Upfitters may find it more practical to disconnect the negative battery terminal than to implement the protective practices outlined above. If choosing this method, the battery should remain disconnected throughout the conversion process. It should be reconnected only to check the function of the Upfitter-added electrical system or to move the vehicle between buildings or to a storage lot.
- Battery cable terminal attaching bolts, which are disconnected by an Upfitter, must be torqued to 17.0 ± 3.0 Nm when reinstalled. Do not over-torque.
- Always reconnect the positive battery cable first, if both the positive and negative cables have been disconnected. This will reduce the potential for accidentally short-circuiting the battery to ground.
- Care should be exercised when removing and/or reinstalling battery terminal attaching bolts. Inadvertent grounding of the positive terminal can result in severe arcing that could cause injury to the operator.

Charging Procedures

If it is necessary to jump-start a vehicle or recharge an OEM battery, make sure that all charger/cable connections are clean and tight. Refer to the appropriate GM Service Manual and/or Owner’s Manual for jump starting procedures. The proper charging procedure follows:

1. Connect the positive lead from the charging device to the positive terminal of the battery.

2. Attach the negative lead from the charging device to a grounded metal vehicle component, away from the battery.

   ◆ Do not attach the negative lead to the braking system’s master cylinder or to any electrical/electronic component housing. Doing so can cause damage to the Anti-Lock Brake System (ABS) module or internal components of the electrical/electronic device.

3. Select the charger setting that will render the highest charge rate for 12-volt batteries. Set adjustable chargers at 16 volts.

4. Fully charge the battery.

◆ Batteries should be checked every hour while on charge.

◆ Discontinue charging if the battery becomes hot (125°F), gasses violently or spews electrolyte through the vents. To avoid a potential explosion, perform this procedure only in a well-ventilated area, away from any flame- or spark producing source. Failure to do so may cause serious bodily injury.

◆ Always turn the ignition switch to the “OFF” position when connecting or disconnecting the battery charger or jumper cables. Failure to do so can damage the various control modules, the radio or other electronic components.

(continued on next page)

◆ Never charge a frozen battery.

OEM and Auxiliary Battery Guidelines (continued)

OEM BATTERY RELOCATION GUIDELINES

The following guidelines apply to commercial vehicle conversions. General Motors does not recommend relocating the OEM battery in vans, pickup trucks, or sport-utility vehicles. If it is necessary to relocate the OEM battery, place and position it so that it can make use of the existing battery cables. If this is not possible and longer cables are required, use wire of a proportionately larger gauge.

If relocating the battery requires attaching the negative ground cable to a frame rail, a cable of equal or greater gauge size must be provided between the frame rail and the vehicle engine block. This is necessary because of the heavy electrical loads imposed by the starting circuit.

To ensure proper electrical system operation, refer to the table in Figure 1 to determine the correct battery cable to use.

Combined Length of Positive and Negative Cables	
Cable Guide	Maximum Cable Length in Inches (Copper Core)
4	66
2	107
0	170

Figure 1

Location

GM recommends locating the battery in a well-ventilated area where temperature buildup does not occur. The location should also provide protection against foreign objects which may damage the battery. The vent port areas on the battery ends should be free of obstructions, allowing gases generated during charging to freely dissipate into the atmosphere.

Vibration:

The battery mounting should not allow battery vibration levels to exceed accepted industry standards.

Accessibility

The battery hold-down should be conveniently located, allowing space for tools and hands without the possibility of personal injury. There should be sufficient clearance at both the insulated and grounded terminals so that wrenches can be used without accidental grounding or shorting of the battery. Terminal polarity markings and warning labels should be visible. The battery ground connection must be readily accessible for disconnection as required for vehicle electrical service.

OEM and Auxiliary Battery Guidelines (continued)

Tilt Angles

Commercial vehicle converters should install the battery so that it is horizontally level (at GVW) under normal vehicle operations. It should not be necessary to tip or tilt the battery more than 40 degrees to install or remove it from the vehicle. Tilting the battery in excess of 40 degrees may cause acid spillage. For short-duration vehicle shipment, the battery should not be tilted more than 19 degrees from the horizontal.

Temperature

The temperature of the electrolyte should not be allowed to exceed 60°C on a continuous basis. The electrolyte can tolerate infrequent peak temperatures of up to 75°C in soak situations only. Shielding may be required to protect the battery from excessive heat sources.

AUXILIARY BATTERY GUIDELINES

Proper location, installation and connection of an auxiliary battery is important to the overall performance of the vehicle's electrical system.

General Information

⚠ Depending on its location in the vehicle, adding an auxiliary battery may affect barrier crash performance. Related testing and certification may be required and is the responsibility of the Upfitter.

Location

⚠ Whenever possible, Upfitters should install auxiliary batteries in locations that eliminate the need for venting and provide for easy service accessibility. Batteries should be located outside the passenger compartment, either in the engine compartment or under the floor pan. GM also recommends installing auxiliary batteries as close as possible to the OEM battery, to minimize voltage drop and cable gauge requirements.

Auxiliary batteries should be located in an area that does not expose the electrolyte to temperatures in excess of 60°C.

If space limitations make it necessary to install the auxiliary battery within the interior of the vehicle (i.e., the luggage compartment or the passenger compartment), the luggage compartment is the recommended alternative. In such cases, to prevent injury to vehicle occupants, strict adherence to the following guidelines is necessary:

- Make sure to house the auxiliary battery in a battery box that is sealed from the vehicle's interior environment and vented to the vehicle's exterior. Battery boxes should also provide a means of draining to the vehicle's exterior any fluids that may accumulate in the battery tray.
- Do not install batteries inside compartments that also contain spark- or flame-producing equipment, such as electric motors, switches or relays as charging operations can generate the formation of explosive hydrogen gas.
- Locate auxiliary batteries in an area of the vehicle that allows easy access for replacement and charging of the battery. See "Serviceability" in the Electrical System Design Guidelines section.

OEM and Auxiliary Battery Guidelines (continued)

Venting

As mentioned earlier, all batteries located in the passenger or luggage compartments should be vented to the outside of the vehicle. Maintenance-free batteries should also comply with this venting guideline as they contain small vent holes through which explosive hydrogen gas can escape during charging.

Mounting and Fastening

Regardless of location, all auxiliary batteries should be securely mounted and fastened to a battery tray that is securely fixed to the vehicle. This will restrict the battery's movement during normal vehicle operations and especially during impact or rollover accidents.

Connecting and Grounding

Use only General Motors OEM-approved connecting devices whenever making connections to the auxiliary battery.
Always connect auxiliary batteries in parallel with the OEM battery.
Under the following conditions, the auxiliary battery should be connected to include within its circuit a device (such as an isolator, relay or switch) that will electrically separate it from the OEM battery:

- When the auxiliary battery is used strictly as a back-up source of electrical power for engine cranking.
- When the auxiliary battery is used exclusively to power electrical devices added by the Upfitter.

⚠ To minimize electrical resistance and maintain full output voltage at electrical devices, auxiliary batteries should be securely grounded to the vehicle engine block.

If the frame must be used as ground return for the added auxiliary battery then an equivalent sized cable must be added from the frame to the engine block. Do not simply ground the battery to the frame without supplementing the return path to the engine block.

Cable Sizing

When installing an auxiliary battery, it is important to specify the correct gauge size of battery cables. Make sure that:

- The gauge size is appropriate for the cable length to minimize voltage drop.
- The cable gauge size is capable of supporting the maximum total current requirement that will be imposed upon the auxiliary battery.

⚠ If the auxiliary battery is wired in parallel with the OEM battery, its cable gauge sizes should be equal to, or greater than, the gauge sizes of the OEM battery cables

OEM and Auxiliary Battery Guidelines (continued)

BATTERY CABLE SAE J1127 CONVERSION/CONSTRUCTION TABLE			
Metric Size	English Gauge	Metric Construction*	Metric Area
13mm^2	6 ga.	37/.66	12.658mm2
19	4	61/.63	19.015
32	2	127/.57	32.407
32	2	7x19/.57	33.938
40	1	127/.63	39.589
40	1	7x19/.63	41.459
50	0	127/.71	50.282
50	0	7x19/.71	52.657
62	2/0	127/.79	62.251
62	2/0	7x19/.79	65.192
81	3/0	7x37/.63	80.737
103	4/0	7x37/.71	102.543
* No. of Strands/Strand Diameter in mm			

Figure 2*

**The table in Figure 2 provides information that can help to select the correct cable gauge size.*

BATTERY DISCHARGE LIMITER GUIDELINES

The design and installation of battery discharge limiting devices, which are installed in GM vehicles by Upfitters, should comply with the following recommendations:

- Be designed to conform to all applicable recommendations outlined in the “Electrical Component Guidelines” sub-section of the Electrical System Design Guidelines section of this manual. Do not require that battery cable(s) be cut.
- Be designed to accept unmodified OEM battery cable terminals.
- Incorporate OEM-type battery terminals for the attachment to the OEM battery.
- Attach to the battery with GM-approved bolts.
- Be designed so that if attached directly to the battery, the limiter electrical interface connection be compatible with the battery terminal (post) mating surface (i.e., will make full surface terminal-to-terminal contact). This will allow a solid and tight battery interface connection to be made which will ensure that the vehicle’s electrical system is not degraded. The bolt used to attach the limiter to the battery post must be the correct length and should conform to OEM configuration, material and terminal interface requirements. Care must be exercised not to over-torque this bolt (see “OEM Battery Guidelines,” General Information — this manual section).

OEM and Auxiliary Battery Guidelines (continued)

BATTERY DISCHARGE LIMITER GUIDELINES (continued)

This section contains guidelines and recommendations to assist the Upfitter when interfacing electrical connections to the host OEM wiring system. Improper electrical connections can result in failures of both the Upfitter and OEM electrical systems.

To the maximum degree possible, Upfitter electrical systems should be functionally separated from the OEM electrical system. This will help to prevent potential failures and/or damage to the OEM electrical system in the event there is an Upfitter electrical system failure.

Electrical System Interfacing – New Circuit Guidelines

NEW CIRCUIT GUIDELINES

To prevent the OEM circuit protection device and/ or the OEM electrical cable from becoming overloaded, GM generally recommends against:

- Adding new circuits to existing OEM fuses and circuit breakers, except as noted in this section of the manual, Upfitter Integration group bulletins and/or New Features booklets and specific model year GM Body Builders Manuals.
- Splicing into OEM circuits to obtain power pick-up feeds for new circuits, except under the conditions outlined in this section of the manual, in upfitter Integration group bulletins and/or New Features booklets and specific model year GM Body Builders Manuals. See 'www.gmupfitter.com' for additional information.

Interfacing to the OEM Electrical System

GM recommends that the Upfitter gain access to the OEM electrical system by way of the provided connectors, electrical convenience centers and/or battery studs and as explained in the electrical section of the specific GM Body Builders Manuals, Upfitter Integration group bulletins and/ or New Features booklets. See 'www.gmupfitter.com' for additional information.

When interfacing with the OEM electrical system to add a new circuit, always observe the following:

Never cut into an OEM wire if an alternate method, such as a connector, electrical convenience center, battery stud, etc., is available to gain access to the OEM electrical circuit.

- Always incorporate a circuit protection device into all new Upfitter added circuits that are not specifically protected by an OEM overcurrent protection device. (See “Circuit Protection Guidelines” under the Electrical System Design Guidelines section.).
- Always conduct an electrical-load study for each circuit and keep the resulting data on file to assure that the added electrical load, combined with any existing OEM loads, will not exceed 80% of the rating for the circuit protection device being used.

⚠ Never replace OEM fuses and/or circuit breakers with fuses and circuit breakers of a higher rating in an attempt to meet the 80% criteria requirement.

- Always use the correct polarized (indexed) connector to interface with OEM connectors and/or convenience centers.
- Ignition accessory and battery feeds, other than those specifically provided for upfitter usage, should only be used to provide a signal source to a relay coil that draws a maximum of one (1) ampere of current. Do not use them to supply direct power to Upfitter-added ignition-controlled or battery-fed electrical devices.
- The adding of Upfitter electrical loads to OEM dimmable lighting circuits is not recommended due to the potential to electrically overload the OEM electronic control device.

Electrical System Interfacing – Extending OEM Circuit Guidelines

- Always use the appropriate gauge of wire for the added circuit. Select a wire gauge that is capable of supporting the maximum load to which the added circuit will be exposed. (See "Cable (Wire) Selection Guidelines" under the Electrical System Design

- If splicing becomes the only alternative for interfacing to the OEM electrical system, the Upfitter should always splice into the OEM wiring in accordance with the splicing guidelines outlined in this manual. Do not use Quick splice, Scotch lock, wire nuts or similar splicing devices in GM motor vehicles.

🚫 GM strongly recommends against interfacing with the OEM electrical system to add an upfitter-installed vehicle remote start system. Doing so creates the potential for detrimentally affecting the vehicle electronics and the On Board Diagnostic (OBD) systems.

Body Builder Junction Block/Connector

When provided by the OEM, the body builder junction block/connector is powered by direct battery- and ignition-controlled circuits. It should be used to power all Upfitter-added circuits that do not require the interfacing to an OEM control device. Circuit protection should be added within 18 inches of the wire's length from the OEM junction block/connector.

EXTENDING OEM CIRCUIT GUIDELINES

If a connector is provided for Upfitter interfacing, use the mating OEM connector to extend the OEM circuit. Examples of OEM circuits with an interfacing connector are interior lighting and rear speaker circuits. Splicing is less reliable than other connecting methods and is generally not recommended except in cases where the OEM circuit does not have an interfacing connector. In such cases, splicing is acceptable, providing it complies with the recommendations outlined in the "Splicing Guidelines" subhead in the Electrical System Design Guidelines section of this manual. Examples of circuits which do not always provide interfacing connectors are power door lock, front fog lamp and exterior running lamp circuits.

⚠ Caution must be exercised whenever an existing OEM circuit is utilized as the power source for an Upfitter-added circuit. The Upfitter should always incorporate a relay into the system whenever the added load demands a higher current than that which the host OEM wiring or circuit protection device can provide. The OEM wiring can act as a signal source for the relay coil. The relay then channels power from the vehicle battery power-pickup point to the added circuit. The power supply wire extending from the battery power-pickup point should be of the proper size and protected by an appropriate fuse or circuit breaker. (See "Cable (Wire) Selection Guidelines "and "Circuit Protection Guidelines" headings of this Manual.)

⚠ When adding electrical loads to existing OEM circuits, Upfitters should conduct an electrical load study, document its data and keep it on file. Doing so will assure that the OEM wire gauge and circuit protection device is adequate to support the added load. The total circuit current draw (combined Upfitter and OEM electrical loads), should not exceed 80% of the OEM circuit current protection device rating.

Electrical System Interfacing — Extending OEM Circuit Guidelines (continued)

⚠ Never replace OEM fuses and/or circuit breakers with fuses and circuit breakers of a higher rating in an attempt to meet the 80% criteria requirement.

Always use the appropriate gauge of wire for the added circuit. Select a wire gauge that is capable of supporting the maximum load to which the added circuit will be exposed. (See “Cable (Wire) Selection Guidelines” under the Electrical System Design Guidelines section.)

When extending OEM circuits, the OEM wire color coding should be maintained throughout the entire circuit run.

Electrical System Interfacing – Design Guidelines

Design Guidelines

Cable (Wire) Selection Guidelines

Selecting the correct cable (wire) gauge ensures the proper voltage supply to an electrical device and prevents the cable from overheating.

Cable Ampacity

"Ampacity" is the maximum current (in amperes) that a conductor can continuously carry without exceeding the insulation's continuous operating temperature. In short, it is the cable's ampere capacity.

All electrical conductors have some resistance to the flow of electrical current. The resistance of a cable increases as the cross sectional area or gauge decreases. Conversely, cables with a larger cross section have less resistance and thus, a higher ampacity. The current in a cable can cause the cable to heat up due to the conductor's (copper) resistance. When current increases to a level high enough to raise the internal conductor temperature to a point that exceeds the maximum temperature rating of the cable, the insulation begins to degrade. If the circuit does not include an electrical device to limit the current so that it does not exceed the ampacity of the cable, the cable must be sized so that it is protected by the circuit protection element.

Design Recommendations

As a general rule, all Upfitter new and extended circuits should specify wire gauges that have a current-carrying capacity rating of 135% of the circuit's current protection device. Extended circuits should utilize cable of a gauge equal to or greater than the gauge of the host OEM wiring.

Cable gauge reductions are permissible on power feed circuits after the point at which the Upfitter circuit-protection device is added.

Upfitter extensions of OEM wiring should be color coded with the same wire color as the OEM wire being extended. Upfitter-added circuits should also maintain color continuity throughout the entire run of the circuit (from power-pickup point to the device being wired). The marking of the cable's circuit function is also recommended.

Electrical System Interfacing – Design Guidelines (continued)

Cable (Wire) Types

All wiring and insulation should conform to the requirements of SAE J1128 (low-tension primary cable).

- Passenger compartment

— For normal passenger compartment wiring applications, use GPT (general purpose, thermoplastic insulated) type wiring or its equivalent. This type of wire is PVC insulated and has a continuous operating temperature rating of+80°C (176°F).

- Engine compartment

— The engine compartment or any other area where temperatures can exceed +80°C (176°F) requires GXL (general purpose, cross-linked polyethylene insulated) type wiring or its equivalent. This type of wire has a continuous operating temperature rating of +135°C (275°F).

Cable (Wire) Gauge Selection

To choose the appropriate cable gauge when adding new circuits or extending existing circuits, follow the steps below. This selection process should be applied for all power, signal and ground circuit requirements.

1. Determine the maximum current (load) the cable is expected to carry.
2. Determine the length of cable needed to extend from the power source to the load. (Note: If the device uses a ground wire, also include the length of the ground wire in this calculation.)
3. Refer to Table 1 on the following page to determine the initial (preliminary) gauge of cable for the wire length and current requirements established in steps 1 and 2 above. (Note: The length number used must match or exceed the total wire length requirement.)

Electrical System Interfacing – Design Guidelines (continued)

TABLE 1

		CURRENT DRAW IN AMPERES																			
GAUGE SIZES		1	2	3	4	5	6	7	8	9	10	15	20	25	30	40	50	60	70	80	100
Metric	**English**	**MAXIMUM LENGTH OF SAE J1128 CONDUCTOR (in feet) FROM POWER SOURCE TO DEVICE** (see ground circuit note in length determining process)																			
.5mm^2	20	107	53	36	27	21	18	15	13	12	11	7									
.8mm^2	18	172	86	57	43	34	29	25	21	19	17	11	9								
1.0mm^2	16	261	130	87	65	52	43	37	33	29	26	17	13	10							
2.0mm^2	14	413	207	138	103	83	69	59	52	46	41	28	21	17	14						
3.0mm^2	12	651	326	217	163	130	109	91	81	72	65	43	33	26	22	16					
5.0mm^2	10	1043	521	348	261	208	174	149	130	116	104	70	52	42	35	26	21	17			
8.0mm^2	8	1653	827	551	413	331	276	236	207	184	165	110	83	66	55	41	33	28	24	21	
13.0mm^2	6	2892	1446	954	723	578	482	413	362	321	289	193	145	116	96	72	58	48	41	36	29
19.0mm^2	4	4170	2085	1390	1043	834	695	596	521	463	417	278	209	167	139	104	83	70	60	52	42

4. Determine the maximum ambient temperature to which this wire will be subjected, under all vehicle operating conditions.

5. Determine the type of cable required, GPT +80°C or GXL +135°C. This decision should be based on the maximum ambient temperature determined in step 4.

6. Using the maximum ambient temperature figure determined in step 4, locate the temperature figure that matches or exceeds this temperature in Table 2 on page 16 for GPT wire or Table 3on page D-3 for GXL wire and compare the ampacity rating for that temperature and the preliminary wire gauge you selected from Table 1. If this ampacity rating is equal to or greater than the ampacity rating from Table 1, use the original (preliminary) gauge you selected from Table 1. If the ampacity is less than the ampacity of the gauge of wire selected from Table 1, follow the temperature column down until you reach an ampacity that meets or exceeds your circuit's maximum current-carrying requirement. Follow that ampacity number horizontally to the left, in the table you are using, to determine the new correct cable gauge to be used.

Electrical System Interfacing – Design Guidelines (continued)

CABLE CONVERSION CHART – METRIC vs. ENGLISH LOW-TENSION PRIMARY CABLE – SAE J1128			
Metric	**English**	**Metric**	**English**
. 5mm^2	20 Ga.	5.0mm^2	10 Ga.
.8mm^2	18 Ga.	8.0mm^2	8 Ga.
1.0mm^2	16 Ga.	13.0mm^2	6 Ga.
2.0mm^2	14 Ga.	19.0mm^2	4 Ga.
3.0mm^2	12 Ga.		

Figure 3

The cable conversion chart in Figure 3 is provided for reader convenience in converting English wire gauges to Metric equivalents.

TABLE 2

GPT STANDARD WALL CABLE – 80°C MAXIMUM RATING CABLE – AMPACITY vs. AMBIENT TEMPERATURE

GAUGE SIZES		AMBIENT TEMPERATURE										
		25°C	30°C	35°C	40°C	45°C	50°C	55°C	60°C	65°C	70°C	75°C	80°C
Metric	English	77°F	86°F	95°F	104°F	113°F	122°F	131°F	140°F	149°F	158°F	167°F	176°F
MAXIMUM AMPACITY – GPT (PCV) STANDARD WALL CABLE													
.5mm^2	20	16	15	14	13	13	12	11	9	8	7	5	0
.8mm^2	18	20	19	18	17	16	15	13	12	10	8	6	0
1.0mm^2	16	25	24	23	21	20	18	17	15	13	10	7	0
2.0mm^2	14	34	32	30	29	27	25	22	20	17	14	9	0
3.0mm^2	12	45	43	40	38	35	33	30	26	23	18	13	0
5.0mm^2	10	60	57	54	51	48	44	40	35	30	25	17	0
8.0mm^2	8	80	76	72	68	64	59	53	47	41	33	23	0
13.0mm^2	6	112	107	101	95	89	82	75	67	57	46	32	0
19.0mm^2	4	147	140	132	125	116	107	98	87	75	60	42	0

Electrical System Interfacing – Design Guidelines (continued)

TABLE 3

GXL STANDARD WALL CABLE – 135°C MAXIMUM RATING – CABLE AMPACITY vs. AMBIENT TEMPERATURE

GAUGE SIZES		**AMBIENT TEMPERATURE**																
		25°C	**50°C**	**65°C**	**70°C**	**75°C**	**80°C**	**85°C**	**90°C**	**95°C**	**100°C**	**105°C**	**110°C**	**115°C**	**120°C**	**125°C**	**130°C**	**135°C**
Metric	**English**	**77°F**	**122°F**	**149°F**	**158°F**	**167°F**	**176°F**	**185°F**	**194°F**	**203°F**	**212°F**	**221°F**	**230°F**	**239°F**	**248°F**	**257°F**	**266°F**	**275°F**
	MAXIMUM AMPACITY – GXL STANDARD WALL CABLE																	
0.50mm^2	20	22	20	18	17	16	16	15	14	13	13	12	11	9	8	7	5	0
0.80mm^2	18	28	25	23	22	21	20	19	18	17	16	15	13	12	10	8	6	0
1.00mm^2	16	35	31	28	27	26	25	24	23	21	20	18	17	15	13	10	7	0
2.0mm^2	14	48	42	38	37	35	34	32	30	29	27	25	22	29	17	14	10	0
3.0mm^2	12	63	56	51	49	47	45	43	41	38	36	33	30	27	23	19	13	0
5.0mm^2	10	85	75	68	66	63	61	58	55	52	48	45	41	36	31	25	17	0
8.0mm^2	8	114	101	92	88	85	81	77	73	69	65	60	54	49	42	34	24	0

Typical Calculation Example

You have calculated that the maximum load to which your circuit will be subjected is 20 amps and your total circuit wire length is calculated to be 20 feet. Read down the 20 amp column in Table 1 until you find a length of wire that matches or exceeds your 20-foot requirement. In this case it is 21 feet. Read across to the left of this number to determine the wire gauge size to be used. You will find it to be 14 gauge (2.0 mm$_2$ metric). This is your initial (preliminary) gauge requirement.

You have determined that the maximum ambient temperature this wire will be exposed to is 65°C (149°F) and you opt to use GPT cable. Read down under the 65°C column and across from the 14 gauge listing in Table 2 and you find that 17 amps is the maximum ampacity for a 14 gauge wire that will be exposed to a temperature of 65°C. As 17 amps is less than your 20 amp requirement, continue reading down the 65°C column until you reach an ampacity that matches or exceeds your 20 amp requirement. In this case it is 23 amps. Read across to the left of this number to determine your new wire gauge requirement which you will find to be 12 gauge (3.0 mm$_2$ metric). This is your new wire gauge requirement.

Electrical System Interfacing – Design Guidelines (continued)

WIRE HARNESS ASSEMBLY GUIDELINES

Design Recommendations

To help ensure a quality electrical build, GM recommends that Upfitters group individual wires together and bundle them into a harness assembly for their protection. This harness assembly should be preassembled outside the vehicle and should be built in accordance with the recommendations outlined in the “Cable (Wire) Selection Guidelines,” “Connecting Guidelines” and “Wire Harness Covering Guidelines” in this section. GM also recommends against the use of common, interchangeable, wire harness assemblies that are not specifically designed and tailored to fit the vehicle into which they will be installed. Universal wiring harness assemblies, that are designed to fit many vehicles and usually incorporate circuits that are not always required or used, tend to create conditions that are usually detrimental to a quality electrical build (e.g., open, loose connectors that are susceptible to short circuiting and rattling; unprotected excess wire that gets stored in areas of the vehicle where it shouldn’t be and becomes susceptible to damage by hostile vehicle surfaces and/or components; wire takeout points that do not always get located in the vehicle where they should be). The overall result is a wiring installation process that becomes very difficult to implement on a repetitive basis.

CONNECTING GUIDELINES

Design Recommendations

In order to achieve a high degree of reliability, it is essential to use a quality connection system whenever an Upfitter electrical system is installed in a GM vehicle. General Motors strongly recommends using OEM connection system components when adding a wiring system to a GM vehicle. For greater reliability, it is recommended that Upfitters use single cavity male/female connectors, rather than butt-splice sleeves, for single wire connection points. (**Note:** If using butt-splice sleeves, make sure that they comply with the recommendations outlined in the “Splicing Guidelines” subhead in this section of this manual.)

General Motors also recommends the following practices:

- The use of multiple-cavity locking connectors that incorporate an indexing feature when more than one set of wires must be connected at a common location. Using this type of connector (instead of individual single connectors or butt-splice sleeves) reduces the number of potential disconnect points.

- Some Upfitter-installed components (i.e., radios, televisions, A/C units, lamps, switches, relays, etc.) require the connecting of multiple circuits. To reduce the number of potential disconnect points, select components that include one of the following design features:

  — Capable of accepting a panel-mount, direct plug-in multiple connector.

  — Incorporates a wiring pigtail that terminates in a multiple cavity connector.

Electrical System Interfacing – Design Guidelines (continued)

- Make sure that all Upfitter electrical connections, except ground connections, are insulated with a connector body or sleeve. This protects against accidental electrical short circuiting, both during and after the wiring installation process.

- Use electrical terminals with incorporated grip wings to relieve wire strain and improve wire retention. (See instructions for “Assembling Connection Systems” in this section.)

- Machine crimp all Upfitter-applied electrical terminals, using an appropriate crimp die. If it is necessary to crimp terminals by hand, they should also be soldered to the wire to ensure a reliable electrical connection. (See “Terminal Removal” and “Soldering Guidelines” in this section.)

- Use only sealed, moisture-proof connectors for making connections outside the passenger compartment. Sealed connectors are not necessary on the vehicle’s interior, unless there is a chance that they will be exposed to high-moisture conditions. (See Sealed and Unsealed definitions in this section.)

- Use ground terminals made of brass or a copper alloy. They should also be tin plated if they will be exposed to a corrosive environment. To eliminate potential corrosion problems, do not use steel terminals, even if they are tin plated. GM recommends using OEM-type ground terminals or their equivalent for all grounding requirements.

- Use ring terminals with incorporated, internal locking teeth at all grounding screw locations. This ensures a positive ground connection. (See Figure 4.)

- For a reliable connection, select ring terminals that are compatible with the size of the stud, screw or bolt that will be used to attach them to the vehicle.

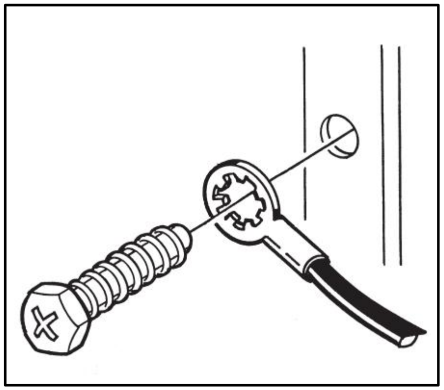


Figure 4

Electrical System Interfacing – Design Guidelines (continued)

CONNECTOR TYPES

Replace with GM Original Equipment (OE) connection systems, utilizing both sealed and unsealed connectors.

Unsealed Connectors

Unsealed connections (Figure 5) are designed for use in the interior of the vehicle. If used elsewhere, environmental factors, such as moisture and grit, can cause corrosion to build up, leading to a poor connection. Corroded terminals create high resistance in the connection, which in turn can cause intermittent or open circuits.

Sealed Connectors

Sealed connection systems (Figure 6) are designed with environmental seals to keep out moisture and grit. This makes them ideal for use outside the vehicle's passenger compartment. Built into this type of connector are two types of seals:

- A connector seal which provides an environmental seal between the mating connectors.
- A cable seal which seals the area where each wire enters the connector.

General Motors recommends using sealed connection systems in areas exposed to the outside environment.

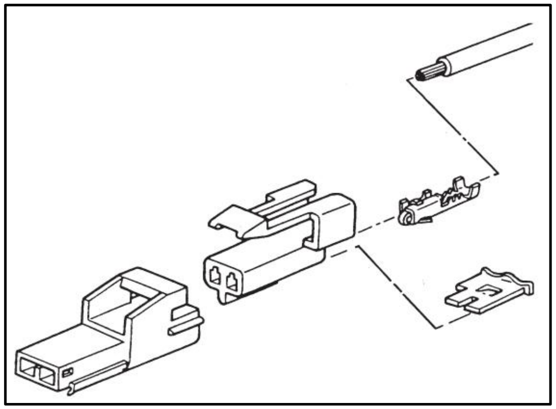


Figure 5

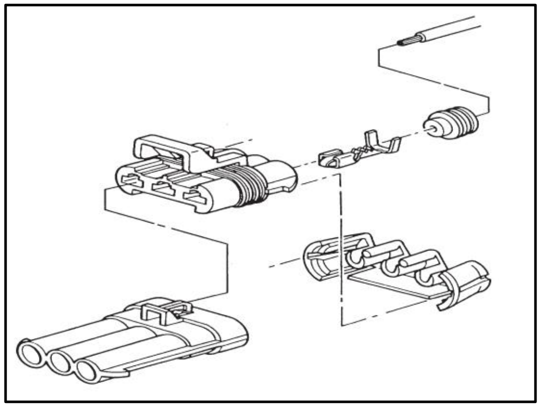


Figure 6

Electrical System Interfacing – Design Guidelines (continued)

HOW TO CHOOSE A CONNECTION SYSTEM

Follow the steps below to determine the best connection system for a particular application.

1. Determine the environment to which the connection will be exposed.

    — For connections inside the vehicle, use an unsealed connector.

    — For connections outside the vehicle, use a sealed connector.

2. Use the charts in Figures 7 and 8 to determine the best available connection type.

3. Determine the number of circuits needed in the connection.

4. Refer to Appendix II of this manual for additional details to select the appropriate style connector for your application.

Terminals

Terminals vary in several ways. Understanding these variations is essential in choosing the proper connection system and terminal. Typically, terminals can vary according to:

- Size (blade width or series)
- Type of material or plating
- Size of core grip wings
- Size and type of insulation grip wings

Electrical System Interfacing – Design Guidelines (continued)

Terminal Characteristics

Terminals are made of different materials and can be either plated or un-plated. Plated terminals are more corrosion resistant and, therefore, are recommended for connections in a corrosive environment. The terminal's core grip wings are designed to accommodate different gauge size wires. Small core grip wings are suitable for small gauge wire, large core grip wings for larger gauge wire. Because of this, it is essential to know the wire size to select the correct terminal.

Terminal Examples

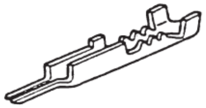
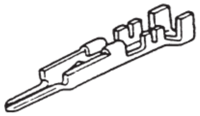
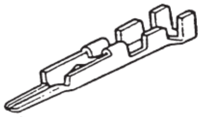
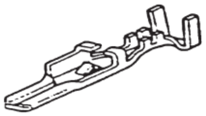
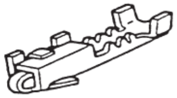
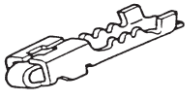
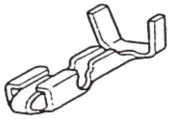
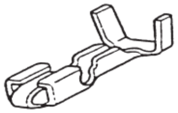
Male				
Female				
Maximum Current Rating	14 amps	30 amps	42 amps	46 amps

Figure 8*

***Note for Figures 7 and 8:** These values may vary depending on the environment in which the terminals are used (e.g., engine compartment, cab, chassis, etc.) due to temperature effects and other considerations. It is recommended that the upfitter test the terminal in the application in which it is intended to be used to ensure that the current capacity is adequate.*

Electrical System Interfacing – Design Guidelines (continued)

The current draw of each circuit in a connector system must first be known to enable the correct terminal series to be selected. Insulation grip wings are designed to be crimped over the wire insulation in an unsealed connection system, and over the cable seal in a sealed connection system. Terminals meant for use in a sealed system are not interchangeable with those intended for an unsealed system.

Insulation grip wings for sealed systems are generally larger than their unsealed system counterparts. The more rounded shape of the larger grip wings allows them to work well with the round cable seal used in a sealed system.

⚠ Due to the many factors involved in the selection of terminals and cable seals, terminal and cable seal part numbers are not included in Connector System Parts List (Appendix II). For reader convenience in determining the correct terminal usage, a millimeter-to-inches conversion table for cable outside diameter follows (Figure 9).

CONVERSION TABLE FOR CABLE O.D. – MILLIMETER TO INCHES	
CABLE O.D. (mm)	CABLE O.D. (in.)
1.29 - 1.70	0.051 -0.067
1.60 -2.15	0.063 -0.085
1.65 -2.15	0.065 -0.085
1.84 -2.25	0.072 -0.089
1.90 -2.64	0.075 -0.104
2.01 -2.85	0.079 - 0.112
2.03 -2.42	0.080 -0.095
2.03 -2.42	0.080 -0.095
2.03 -2.85	0.080 -0.112
2.81 -3.49	0.111 - 0.137
2.81 -3.75	0.111 -0.148
2.89 -3.65	0.114 -0.144
3.45 -4.30	0.136 -0.169
3.61 -4.50	0.142 -0.177
3.72 -4.48	0.147 -0.176
4.40 -5.15	0.173 - 0.023

Figure 9

Electrical System Interfacing – Design Guidelines (continued)

ASSEMBLING CONNECTION SYSTEMS

To assure a quality crimp, General Motors recommends machine crimping, using an appropriate crimp die. If it is necessary to crimp terminals by hand, follow the procedures outlined in the section(s) below.

Terminating a Wire (Hand Crimped)

Terminating a wire requires the following tools:

- Wire cutters
- Wire strippers
- Terminal crimp tool (ratcheting-type preferred)
- Soldering iron or Ultra-torch

General Motors recommends the following procedure for terminating a hand-crimped wire:

⚠ Sealed connection systems require specific or different assembly steps as noted in the procedure.

1. **FOR SEALED CONNECTION SYSTEMS ONLY**: Slide the appropriate cable seal onto the wire end to be terminated as shown in Figure 10.
2. Using wire strippers, strip about 3/8" of insulation off of the wire (Figure 11). Be careful not to cut the wire strands.

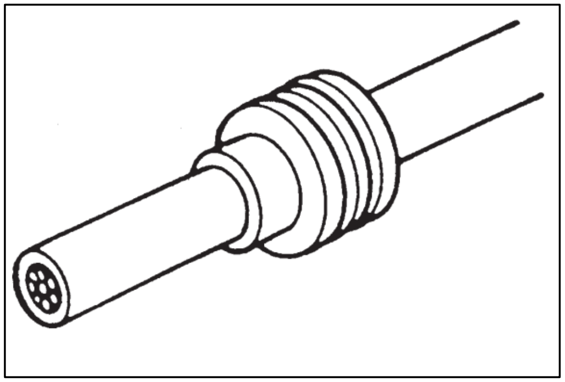


Figure 10

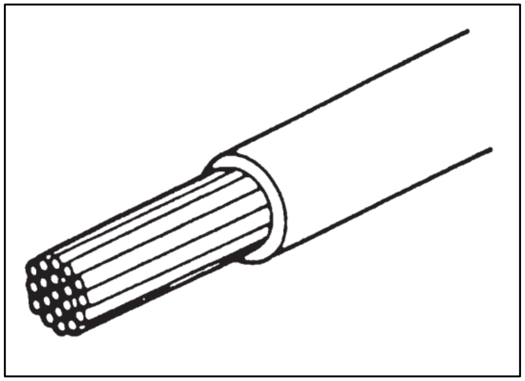


Figure 11

Electrical System Interfacing – Design Guidelines (continued)

3. Inspect wire strands. If they have been cut, use wire cutters to cut off stripped portion of wire and strip again.
4. Place wire in terminal core and insulation grip wings. There should be enough core exposed so that it extends just beyond the end of the core grip wings on both sides, with the insulation lying between the insulation wings (see Figure 12).

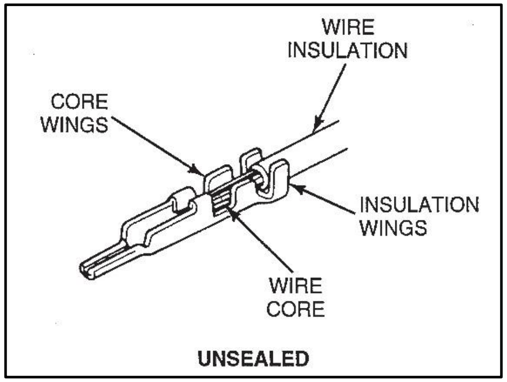

WIRE INSULATION
CORE WINGS
INSULATION WINGS
WIRE CORE
UNSEALED

Figure 12

If using a sealed system, the cable seal should rest within the terminal insulation wings as shown in Figure 13. If the core extends too far past the end of the core grip wings, it can interfere with the mating of the terminal.

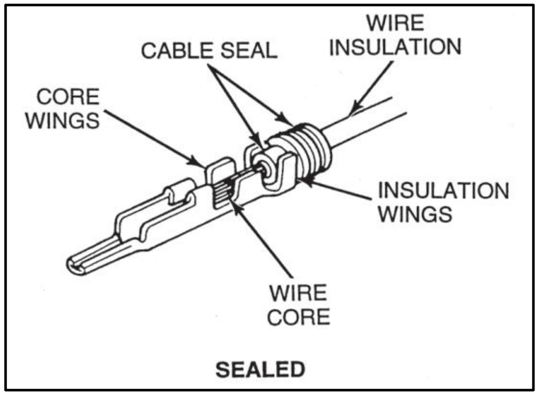

WIRE INSULATION
CABLE SEAL
CORE WINGS
INSULATION WINGS
WIRE CORE
SEALED

Figure 13

Electrical System Interfacing – Design Guidelines (continued)

5. Using the appropriate crimping tool, crimp core wings (Figure 14). Use good judgment when applying force. Adhering to the following requirements will help to achieve a good core crimp:

   — Do not bend or crack the terminal.
   — Do not cut the wire strands with the core wings.
   — Make sure that all wire strands are contained inside the core wings.
   — Cable must not fall out of the core wings once they have been crimped.

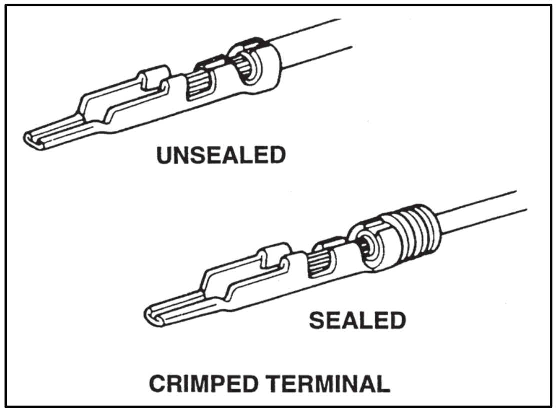


Figure 14

6. Crimp insulation wings using the same procedure as outlined in Step 5. Note that the crimp size is larger for sealed terminal insulation wings than for unsealed. The following will aid in achieving a good insulation crimp:

   — Do not cut into the wire insulation.

   — Do not bend or crack the terminal.

   — Terminal must contact insulation on both top and bottom of crimp area.

   — Do not cut into the cable seal (sealed connection systems only).

6. Solder all hand-crimped terminals. Proper soldering techniques are outlined in “Soldering Guidelines” in this section.
1. Be careful not to use too much solder as wicking can occur. Avoid getting solder on the terminal’s mating interface.

Electrical System Interfacing – Design Guidelines (continued)

SOLDERING GUIDELINES

Production crimps generally do not require soldering because the crimp is made with precision tooling. Hand-crimping cannot meet the same quality standards. Therefore, soldering is recommended to produce reliable connections in hand-crimped terminals. Soldering a crimp is important for two reasons:

- It provides a mechanical bond between the terminal and the wire. This helps to prevent wires from pulling loose and causing an open circuit.
- It reduces the possibility of corrosion-related problems. As the core becomes more corroded, the wire develops a higher resistance to current flow. This may cause electrical components to function improperly.

Soldering Procedures

Soldering a terminal requires a soldering iron. The recommended procedure is:

1. Allow soldering tool to preheat for at least one minute. Preheating promotes good, even solder flow.

   CAUTION Do not use a soldering gun to solder terminals. Even at low settings, soldering gun temperatures are too high for this application.

2. Heat the terminal core wings and wire core. Avoid heating too close to the wire insulation. Burned or melted insulation can lead to short circuits, open circuits, or corrosion within the wire, resulting in high resistance.

3. Apply solder to core wings as shown in Figure 15. Use just enough solder to obtain even solder flow through the core wings.

   CAUTION Use only rosin core/rosin flux solder for soldering terminals. Other flux materials can cause corrosion.

   CAUTION Avoid using too much solder which can result in “wicking.” Wicking results when excessive solder is applied to the terminal and it begins to travel up the wire core, like candle wax up a wick. This can cause the wire to become stiff or brittle and produce a flex point. Eventually, this can lead to a broken wire and an open circuit.

   CAUTION Do not get solder on terminal mating surfaces

4. Check circuit for electrical continuity

(Continued on next page)

Electrical System Interfacing – Design Guidelines (continued)

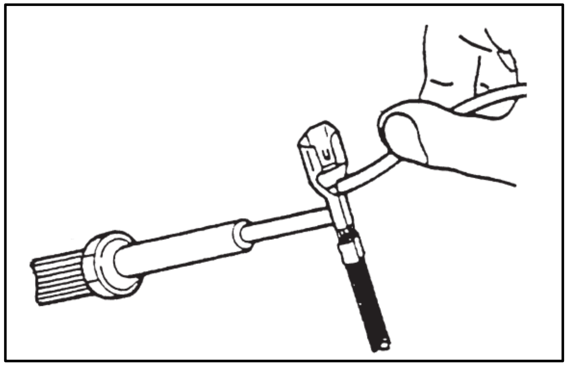


Figure 15

Seating Terminals

No special tools are required for this procedure.

1. Insert the terminal into the connector cavity from the back (non-mating side) of the connector (Figure 16). Push until the terminal “clicks” into the connector cavity.

CAUTION Never use force to insert a terminal.

2. Pull gently on the wire to ensure that the terminal is seated properly and will not pull out from the back of the connector.

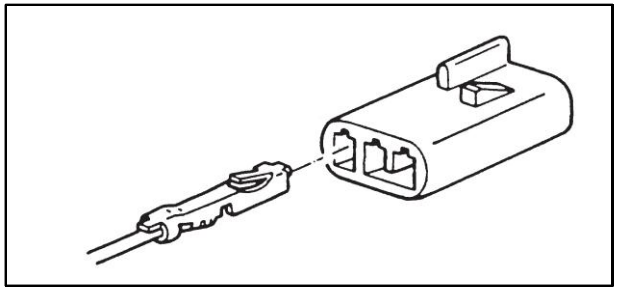


Figure 16

(Continued on next page)

Electrical System Interfacing – Design Guidelines (continued)

Adding secondary or TPA locks

Secondary and terminal position assurance (TPA) locks vary in size and shape, depending on the type of connector being used. Some connectors do not have secondary or TPA locks. Follow the procedures in this section to add secondary locks. These procedures require no special tools.

Unsealed Connector — TPA Lock

Once all terminals have been seated in the connector, the TPA lock can be installed. Push the TPA lock into the back of the connector until it locks into place (Figure 17).

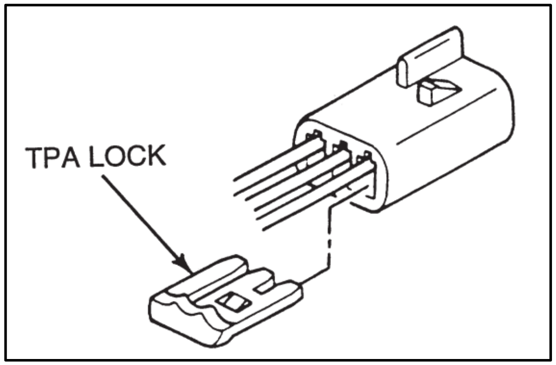


Figure 17

Sealed Connector — Secondary Lock

Once all terminals have been seated in the connector, the secondary lock can be installed. Push the secondary lock over the back of the connector (Figure 18) until it locks onto the connector.

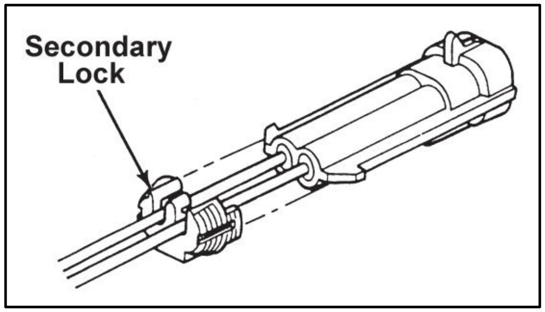


Figure 18

Electrical System Interfacing – Design Guidelines (continued)

Hinged Secondary Locks

Some connectors have hinged secondary locks. Once all terminals have been seated, snap the secondary lock down over the back of the connector as shown in Figure 19.

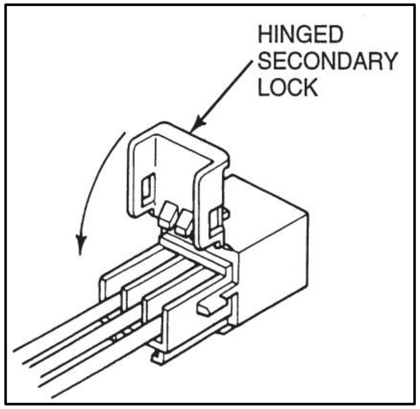


Figure 19

MATING TWO CONNECTORS TOGETHER

Once all terminals have been seated and secondary locks added, mate the two connectors. Simply push them together until the inertia lock snaps into place, locking them together (Figure 20). Pull on the connectors to ensure they are properly mated.

CAUTION Never pull on the wires.

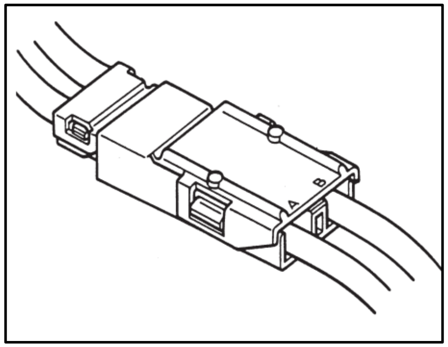


Figure 20

Electrical System Interfacing – Design Guidelines (continued)

DISASSEMBLING CONNECTION SYSTEMS

This procedure can be done using a small screwdriver or pick.

• To remove a connector position assurance (CPA) lock — Remove the CPA lock by simply depressing the tabs on either side and pulling the lock out of the connection. (See Figure 21.)

• To disconnect a connector — using your thumb or a small screwdriver or pick, lift up on the inertia lock tab. Pull the connectors apart.

Removing TPA or Secondary Locks

- To remove a TPA lock — Using a small screwdriver or pick, carefully depress the locking tabs on either side of the connector. (See Figure 22.) Remove the TPA lock from the back side of the connector.
- To remove a secondary lock — Use a small screwdriver or pick to carefully lift the secondary lock over the locking tabs on either side of the connector and remove. (See Figure 23.)

CAUTION Be careful not to bend or deform the locks or connectors if they are to be used again.

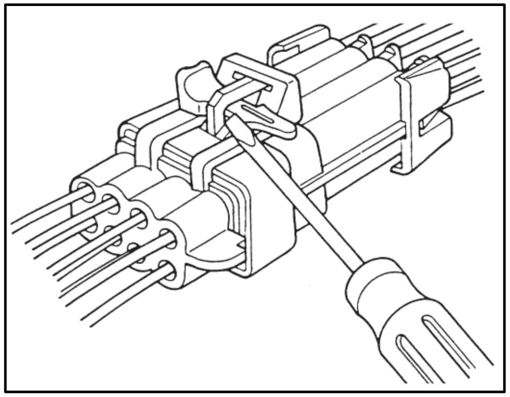


Figure 21

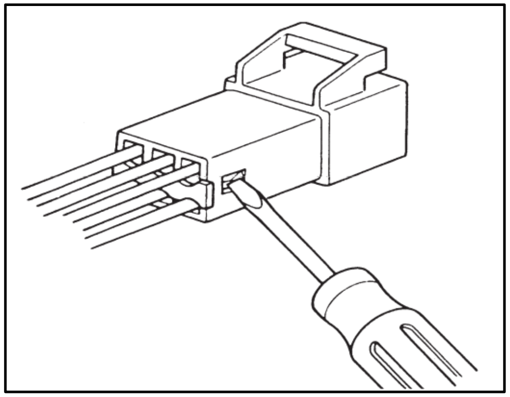


Figure 22

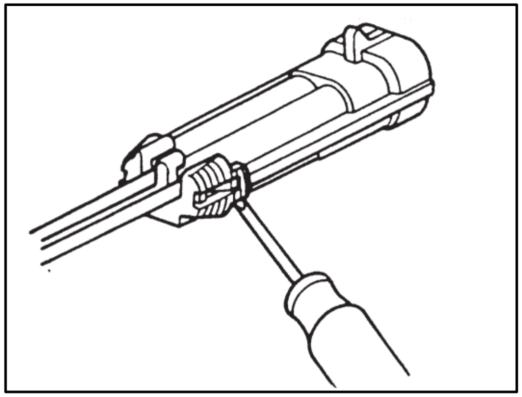


Figure 23

Electrical System Interfacing – Design Guidelines (continued)

TERMINAL REMOVAL

Special tools are required to remove the terminal without damaging it or the connector in which it is inserted. Because connectors are designed to firmly retain terminals, it is sometimes difficult to remove them. Different style terminals have different removal procedures, but most common terminals can be removed using the procedure below. This procedure will work with all parts in the connection systems parts list (Appendix II).

A terminal removal tool (e.g., pick or safety pin) is required to remove a push-to-seat terminal.

1. Disconnect the mating connector.

2. Remove any secondary or TPA lock.

3. Grasp the wire and push the terminal to the foremost position in the connector cavity. Hold the terminal in this position. The terminal locking tang is now separated from the ridge inside the connector cavity. This makes it easy for the terminal removal tool to unseat the terminal.

4. Locate the terminal lock tang in the connector cavity channel by looking into the connector from the mating end.

5. Insert an appropriately sized pick straight into the connector cavity from the mating end of the connector (Figure 24).

6. Depress the lock tang with the pick or pin to unseat the terminal.

7. Gently pull the wire to remove the terminal through the back of the connector.

CAUTION If force is required to remove the terminal, the locking tang has not been properly depressed. Forcing a terminal out of the connector can damage the cavity walls.

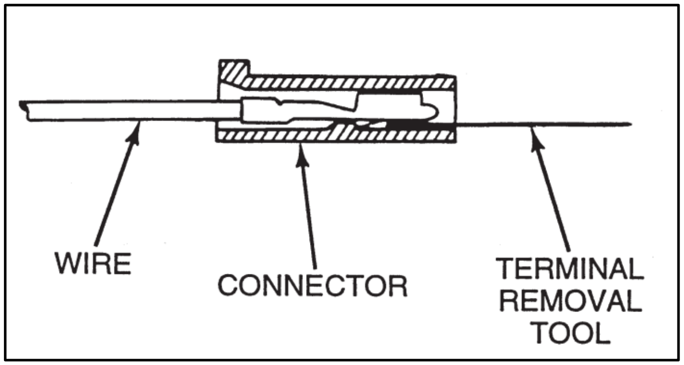


Figure 24

Electrical System Interfacing – Design Guidelines (continued)

Splicing Guidelines

As mentioned earlier, General Motors recommends against splicing into OEM wiring to add or extend a circuit. However, if no other method is available, splicing should comply with the procedures recommended in this section.

CAUTION To ensure a reliable connection, do not use Quicksplice, Scotchlock, wire nuts and/or similar splicing devices in General Motors vehicles.

Splicing Two Wires

The crimp-and-seal splice sleeve is recommended for splicing two wires together. It has several advantages, including:

- It is easy to use. Only one part is needed to complete the splice and it does not require soldering.
- When heated, the glue-lined sleeve bonds to the wire insulation, creating an excellent environmental seal. This makes it perfect for use both inside and outside the vehicle.
- The bond between the splice and the wire, added to the wire crimp, creates a very strong splice.

The table in Figure 27 lists available crimp-and-seal splice sleeves. As previously noted, these parts include a glue-lined tube that, when heated, shrinks over the wires to seal them off from the environment. To assure reliable splicing, always select the splice sleeve properly sized and designed for the wire gauge in use.

The **butt-splice sleeve** can be used for applications that do not require sealing, such as those inside the passenger compartment of the vehicle. It does not, however, create as strong a splice as that of the crimp-and-seal splice. Do not use unsealed butt-splice sleeves for splices that will be located outside the passenger compartment of the vehicle.

Recommended splicing procedure:

1. Strip about 3/8" of the insulation from the ends of the two wires to be spliced (Figure 25).
2. Insert stripped wires into the splice sleeve until they reach the wire stop located at the center of the sleeve (Figure 26).

Electrical System Interfacing – Design Guidelines (continued)

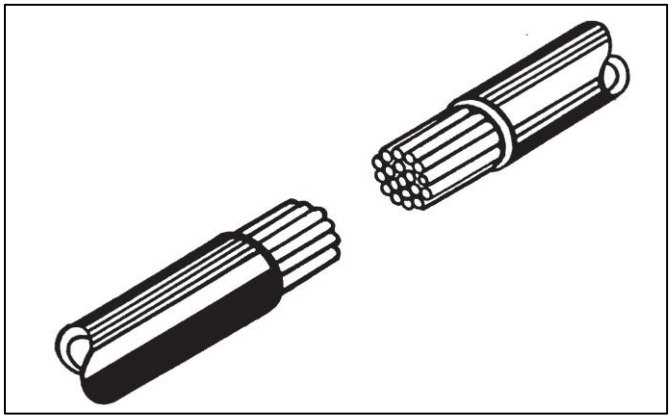


Figure 25

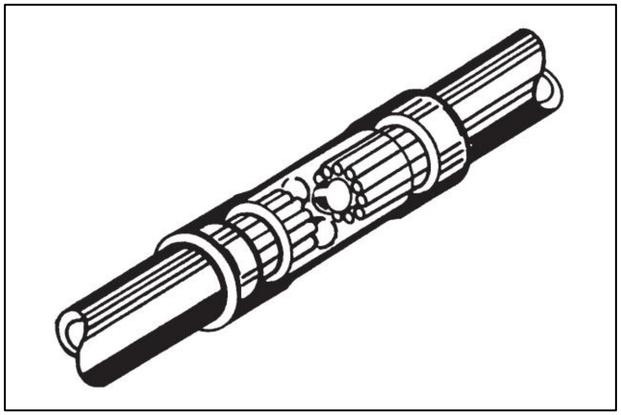
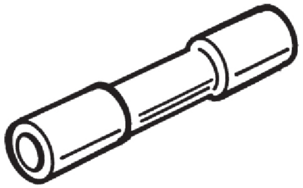


Figure 26

CRIMP-AND-SEAL SPLICE SLEEVE



SLEEVE COLOR	WIRE SIZE	
	English	Metric
Salmon	18-20	0.80-0.50
Blue	14-16	2.00-1.00
Yellow	10-12	5.00-3.00

Figure 27

Electrical System Interfacing – Design Guidelines (continued)

3. Crimp the splice sleeve on each end. Each wire must be crimped individually. For proper placement, see Figure 28.
   (**Note:** Use the appropriate crimp tool designed specifically to use with both crimp-and-seal and butt-splice sleeves.)

4. For crimp-and-seal splice sleeves: Using a hot air gun, apply heat to the splice sleeve. As the sleeve shrinks, the glue inside will begin to melt. When the sleeve stops shrinking and glue appears at the ends of the sleeve (Figure 29), remove heat. Allow to cool.
5. Check for electrical continuity.

⚠ GM recommends against burying in-line splicing devices (that are used in lieu of connectors) in wiring harnesses. Such devices should remain reasonably accessible to service technicians. (See "Serviceability" in this section.)

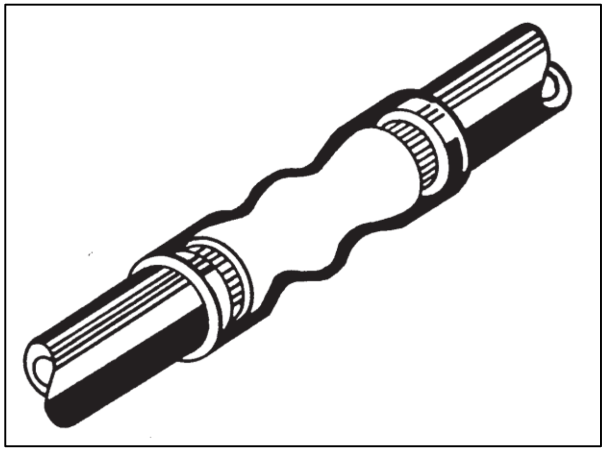


Figure 28

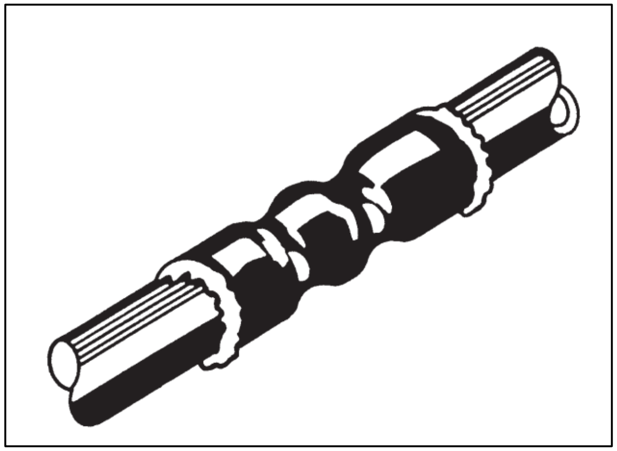


Figure 29

Electrical System Interfacing – Design Guidelines (continued)

Splicing Multiple Wires

The splice clip is the recommended method for splicing more than two wires together. It is similar in function to terminal core grip wings, except the splice clip is designed to accept more than one wire. Splicing is accomplished by placing the wires into the clip, crimping and then soldering them. Soldering ensures a good electrical connection as well as a strong splice. GM recommends using splice tape, heat shrink tubing or glue-lined heat-shrink tubing to protect and insulate the spliced wires.

This type of splice is acceptable anywhere in the vehicle. If used outside the passenger compartment, however, the splice should be appropriately sealed.

Recommended splicing procedure:

1. Strip about 3/8" of the insulation from the ends of the wires to be spliced (Figure 26).
2. The preferred location for any splice is a minimum of 1.5" from another splice.
3. Determine the proper splice clip for the number and size of wires to be spliced. (Refer to “Choosing a Splice Clip “in the “Splicing Guidelines” in this section.)
4. Position the stripped wire ends in the splice clip. The wire core should be visible on both sides of the splice clip (Figure 30).
5. Close the clip securely by hand crimping, using a pair of pliers (Figure 31).

   CAUTION Be careful not to crimp insulation under the splice clip.

6. Apply solder to the splice clip as outlined in the next section.
7. Check circuits for electrical continuity.
8. Cover the splice with splice tape or heat-shrink tubing. The tape or tubing must extend beyond the splice on both sides to cover the edges of the insulation.

   ⚠ If the splice is located outside the passenger compartment, use glue-lined heat shrink tubing for optimum weather sealing.

Electrical System Interfacing – Design Guidelines (continued)

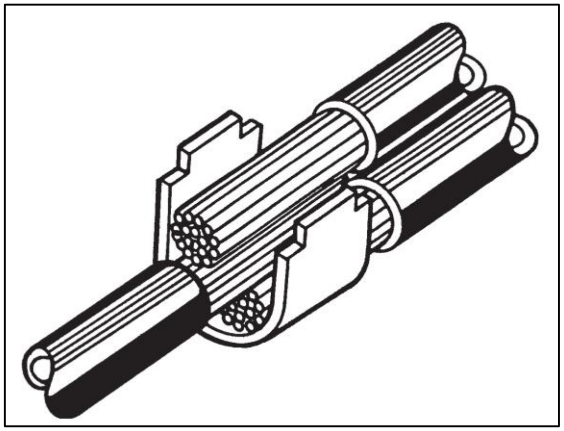


Figure 30

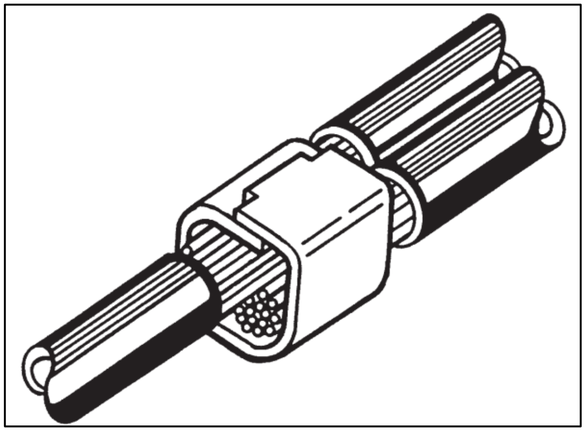


Figure31

Soldering the Splice Clip

As previously noted, soldering helps to ensure a reliable connection and strengthens the splice. Listed below are the recommended steps for soldering a splice clip:

1. Preheat the soldering tool for at least one minute before applying solder. This promotes good, even solder flow.

   ⚠ Do **NOT** use a soldering gun to solder splice clips. A soldering gun gets too hot, even at low settings.

2. Heat the splice clip and wire core. Avoid heating too close to the insulation. Burned or melted insulation can lead to a short circuit, open circuit or corrosion within the wire, causing high resistance.
3. Apply solder to the hole in the splice clip as shown in Figure 32. Use just enough solder to produce an even flow through the splice clip

   CAUTION Use only rosin core/rosin flux solder for soldering splice slips. Other flux materials can cause corrosion.

   CAUTION Avoid using too much solder as it can result in “wicking.” Wicking occurs when excessive solder begins to travel up the wire core, like candle wax up a wick. This can cause the wire to become stiff or brittle and produce a flex point, eventually leading to a broken wire and open circuit.

4. Check circuit for electrical continuity.

Electrical System Interfacing – Design Guidelines (continued)

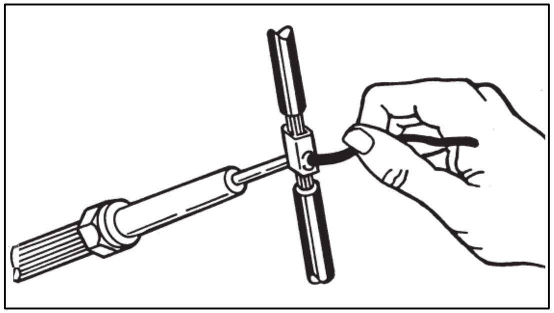


Figure 32

Choosing a Splice Clip

Choosing the right splice clip is extremely important to the overall durability and quality of the splice. Always consider the number and size of wires to be spliced when making a selection.

To determine the best typical splice clip for a particular application, calculate the area of the wire's cross section. Use the optimum range in the table below (Figure 33) to determine the appropriate splice clip part number. The wire cross-sectional areas shown in Figure 34 are for cable. Typical cables do not vary much from these numbers. Simply add up the cross-sectional area for each wire in the splice to get the total cross-sectional area for the splice.

SPLICE CLIP		
SPLICE CROSSECTIONAL AREA mm^2		
	OPTIMUM	**ALLOWABLE**
1	2.16 - 3.29	1.35 - 3.55
2	2.80 - 5.50	2.40 - 6.45
3	5.50 - 8.90	4.0 - 10.85
4	8.90 - 12.15	7.0 - 12.45
5	12.15 - 19.35	9.4 - 21.3
6	21.3 - 35.0	16.0 - 44.75

Figure 33

Wire Size		**CROSSECTIONAL AREA mm2**
ENGLISH (GAUGE)	**METRIC (mm^2)**	**ALLOWABLE**
22	0.35	0.308
20	0.5	0.0549
18	0.8	0.805
16	1	1.177
14	2	1.947
12	3	3.019
10	5	4.757

Figure 34

Electrical System Interfacing – Design Guidelines (continued)

The calculation example below illustrates how to select the appropriate splice clip:

Problem:

Determine the best splice clip to use for a splice with one 12-gauge wire, two 16-gauge wires and one 18-gauge wire.

1. Calculate the total wire cross-sectional area as shown in Figure 35.

2. Using the number just calculated, choose the best splice clip from the preceding splice clip table (Figure 33). The best splice clip for a cross-sectional area of 6.178 mm^2 is item number 6. The optimum range for that clip is 5.50 mm^2 to 8.90 mm^2.

GAUGE	AREA (mm2)	# WIRES	TOTAL
12	3.019	x 1	3.019
16	1.177	x 2	+ 2.354
18	0.0805	x 1	+ 0.805
		Total cross-sectional area (sum of total area for each gauge size) =	6.178

Figure 35

WIRE HARNESS COVERING GUIDELINES

Using the proper wire coverings is an important part of a good electrical system. This section contains GM-recommended wire-covering guidelines for Upfitter-installed electrical systems. Whenever possible, wiring should be bundled into a harness that is prebuilt outside the vehicle. This harness should be covered with some type of protective outer jacket. Protecting wiring with an outer covering reduces the possibility of several common electrical problems. For example, when a wire is pinched or cut, it is usually because it was not where it was supposed to be. Wire coverings bundle wires together and keep them within their designated location within the vehicle. Similarly, when a wire is chafed or burned, it is not uncommon to find that it has rubbed against a sharp object or come too close to a heat source. Protective devices and/or the appropriate wire coverings can eliminate these types of problems. GM recommends Upfitters select and use wire coverings that are appropriate to the environment to which their wiring will be exposed.

Wire Coverings

Common coverings for automotive wiring are tape, profile conduit and convoluted conduit.

(**Note:** See “Wire Routing Appearance Guidelines” when selecting underhood wiring coverings.)

Electrical System Interfacing – Design Guidelines (continued)

Tape

Tape is generally used as either a spot tape or as a harness wrap to keep wires bundled together. It is less costly than convoluted or profile conduit but does not provide much protection against pinching or abrasion. Tape is recommended for use only where minimum or no wire protection is required.

Profile Conduit

General Motors recommends using profile conduit where long, straight runs of wiring are required. Profile conduit protects the wiring by encapsulating it and controlling its position within the vehicle.

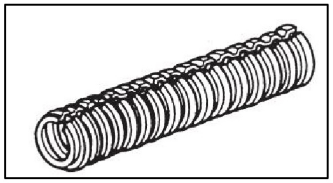
Convoluted Conduit

Where added protection is needed, GM recommends using convoluted conduit to hold wire bundles together. Convoluted is pinch and abrasion resistant and is available in many types and sizes.

- Nylon conduit — provides protection for wiring near heat sources.
- Polyethylene conduit — good for general passenger compartment use.

Both nylon and polyethylene conduits come in a variety of sizes, ranging from 6 mm to 40 mm in diameter.

CONVOLUTED CONDUIT PARTS LIST



Typical Usage:	Passenger Compartment	Engine Compartment
Pitch and Abrasion Resistance	Good	Excellent
Automotive Fluid Resistance	Excellent	Excellent
Color:	Black	Black w/Grey Stripe

DIMENSIONS

Sizes (mm)	6	8	9	10	13	16	19	22	25	30	40
O.D.	9.85	11.65	12.79	14.77	17.33	20.91	24.7	28.68	32.78	37.6	46.7
I.D.	6.35	7.75	8.87	10.4	12.61	15.68	18.86	22.2	25.72	30	41

Electrical System Interfacing – Design Guidelines (continued)

The procedure for determining the appropriate conduit size follows.

⚠ Edges and slits in nylon conduit are sharp surfaces. Wires exiting nylon conduit should be tape wrapped for their protection.

To select the right size of convoluted conduit to use, follow the procedure below:

1. Determine the sum of the diameters of the cables to be covered (S).

2. Select the effective diameter constant (C).

3. Calculate the effective diameter (D).

4. Determine minimum conduit size (inside diameter) required. Choose conduit size based on calculated effective diameter (D).

Selecting Convoluted Conduit:

STEP 1: Determine the sum of the diameter of the cables to be covered (S).					
SIZE		**TWP/TXL THINWALL**		**GPT/GXL STD WALL**	
mm^2	**Gauge**	**mm**	**in**	**mm**	**in**
0.22	24	1.4	0.055	—	—
0.35	22	1.55	0.061	—	—
0.5	20	1.75	0.069	2.11	0.083
0.8	18	2.04	0.08	2.34	0.092
1	16	2.17	0.085	2.56	0.101
2	14	2.58	0.102	2.97	0.117
3	12	3.12	0.123	3.57	0.14
8	8	—	—	5.41	0.213
13	6	—	—	6.76	0.266

Electrical System Interfacing – Design Guidelines (continued)

STEP 2: Select the effective diameter constant (C).

NUMBER OF CABLES TO BE COVERED	CONSTANT C
1	3.15
2	2.58
3	2.18
4	1.95
5	1.74
6	1.58
7	1.48
8	1.39
9	1.29
10	1.21
11	1.15
12	1.11
13	1.07
14	1.03
15	0.99
16	0.95
17	0.98
18	0.95
19	0.93
20	0.91

STEP 3: Calculate the effective diameter (D).

$$\frac{S \times C}{3.1416} = D$$

STEP 4: Determine minimum conduit size (inside diameter) required. Choose conduit size based on calculated effective diameter (D).

CALCULATED EFFECTIVE DIAMETER		CONDUIT SIZE	
mm	in	mm	in
less than 5.3	less than 0.21	6	0.25
5.4 -6.6	0.22 -0.26	8	0.31
6.7 -7.4	0.27 - 0.29	9	0.35
7.5 -8.9	0.30 -0.35	10	0.41
9.0 - 10.7	0.36 -0.42	13	0.5
10.8 -13.5	0.43 -0.53	16	0.62
13.6 -16.0	0.54 -0.63	19	0.74
16.1 -18.5	0.64 -0.73	22	0.87
18.6 -21.3	0.74 -0.84	25	1
21.4 -25.1	0.85 -0.99	30	1.18
25.2 -33.5	1.00 - 1.32	40	1.57

CIRCUIT PROTECTION GUIDELINES

All Upfitter-installed circuits require protection against electrical overload, which can damage not only the circuit but also the vehicle.

Why Is Circuit Protection Needed?

For each size of wire, there is a maximum amount of current that it can carry. When a device fails or a short circuit occurs, the actual current flow may exceed the current-carrying capacity of the wire. When too much current flows through a wire, it may generate enough heat to melt or burn the wire insulation.

⚠ The primary function of circuit protection is to protect the wiring, not electrical devices. In most cases, circuit protection will indirectly protect devices subjected to an overload condition. Many electrical devices, however, contain their own fuses and circuit breakers.

Electrical System Interfacing – Design Guidelines (continued)

When Should Circuit Protection Be Used?

Use circuit protection:

- On all new Upfitter-added circuits
- When using a power feed source (wire from the battery) that is not already protected by some type of circuit protection
- For added safety or to protect a device that could be damaged by too much current
- When splicing into a power circuit with a wire of a gauge size that is smaller than that permitted by the circuit-protection device.

(Note: To avoid this, use a wire of equal or larger gauge when splicing into existing wiring.)

What Types of Circuit Protection Should Be Used?

- **Automotive Type Fuses**

— ATO Fuses (blade type fuse) can be used singly in an individual fuse holder, and/or in multiples, mounted in a fuse panel.

— Automotive glass fuses can be used singly in individual fuse holders or in multiples mounted in a fuse panel.

— Maxi Fuses are newly available, larger, high-current blade type fusing devices which have a slower blow time than high current ATO Fuses. They can be used singly in individual fuse holders or in multiples in a fuse panel.

See Appendix II for automotive fuse part numbers.

- **Automotive Type Circuit Breakers**

— Automatic reset type (cycling) trips and continuously self-resets when subjected to current overload.

— Automatic reset type (non-cycling) trips when subjected to current overload; remains open until power or load is removed.

— Manual reset type trips when subjected to an overload and remains open until it is manually reset.

Electrical System Interfacing – Design Guidelines (continued)

⚠ GM recommends using automatic reset (non-cycling) and manual reset type circuit breakers.

⚠ Terminal and connector part numbers for both ATO Fuse and Maxi Fuse applications can be found in Appendix II. They have been chosen based on using cable. Terminal selection must be based on the outer diameter of the cable insulation.

Circuit Protection Design Recommendations

⚠ Before adding any additional loads to an existing OEM circuit, conduct an electrical load study and document its data. The total circuit current draw, including Upfitter-added loads, should not exceed 80% of the OEM circuit current protection device rating.

⚠ Conduct electrical load studies for all new Upfitter-added circuits to determine the correct circuit protection device rating to use. To avoid nuisance failures, select circuit protection devices with a rating of 125% of the maximum load to be carried by the circuit.

CAUTION Never replace an OEM circuit-protection device with a device of a higher amperage rating.

General Motors also recommends the following:

- Locate fuse holders/panels and/or circuit breakers in the passenger compartment if possible. If located in the engine compartment, they should be environmentally sealed.
- Clearly mark all Upfitter-added fuse holders and fuse panels to indicate both the fuse function and the maximum replacement fuse size(s).
- Clearly mark all Upfitter-added circuit breakers with their maximum amperage rating.
- Install and fasten fuse holders and circuit breakers as necessary to prevent rattling.
- Do not bury in-line fuses in the wiring harness or at random locations. Instead, cluster them together at an access point that is both logical and convenient to the customer/service technician. Provide related service information in the Upfitter owner's manual.
- Install fuse panels in a convenient, customer-accessible location. Provide related service information in the Upfitter owner's manual.
- Limit the number of functions per fuse and/or circuit breaker.

Electrical System Interfacing – Design Guidelines (continued)

The preferred arrangement is one function per fuse or circuit breaker. This makes diagnosis easier in the event of malfunction.

- When adding new circuits to power-added electrical components, wiring should be rated and fused for the components' maximum current draw. Inrush and stall currents should also be considered. (See "Cable (Wire) Selection Guidelines" section.) For owner convenience, the Upfitter should consider providing spare fuses, a special tool for their removal if required, and a diagram or label identifying fuse functions and locations.

ELECTRICAL COMPONENT GUIDELINES

Selecting quality electrical components is essential to the longevity of the vehicle's electrical system. With the exception of normal wear items, such as light bulbs and fuses, all Upfitter-added electrical components are expected to last the life of the vehicle, regardless of the warranty length. General Motors' current design and durability standards specify 10 years and/or 100,000 miles.

When adding electrical devices, it is extremely important to follow all manufacturer instructions on installation and electrical connection(s).

All service replaceable electrical components should be marked with either a vendor or Upfitter identifying part number.

Ratings

To assure that only correctly-rated electrical components are installed, all added current-drawing and/or control devices should be marked to indicate the following:

- Current draw (amperes) or wattage rating (watts) for current drawing devices
- Maximum connected load (amperes) for control devices
- Voltage at which they are designed to function Exceptions to this are devices such as light bulbs, for which current draw and wattage numbers are readily available in industry catalogs.
- All Upfitter-added electrical components should have a DC voltage rating not less than the system voltage. They should also be appropriately marked to indicate their voltage rating. Passive electrical components, such as relays and circuit breakers, should be marked with their maximum ampere current capacity at 12-14 VDC.
- Upfitter-installed switches should have a DC rating of not less than 100% of the expected maximum connected load. Inductive startup and tungsten inrush loads must be taken into consideration when determining the maximum connected load.

Electrical System Interfacing – Design Guidelines (continued)

• Upfitter-installed relays should have a DC current rating of at least 150% of the expected maximum connected load. The additional 50% over specification is to protect the relay from high start-up inductive loads from motors or high inrush tungsten loads from lighting devices.

• Interior lighting devices should be equipped with bulbs with candle-power or wattage rating recommended by the manufacturer. Using bulbs of higher ratings can result in lamp damage due to the high heat generated when lamps are left on for extended periods of time.

Component Tolerance Levels

Upfitter-added components should also be capable of operating when exposed to a variety of conditions. Electrical components should be capable of withstanding:

- Temperatures ranging from –40°C to +85°C.
- Up to 14 volts DC, applied in a reverse polarity direction for a minimum of 30 seconds. Exposure to a reverse polarity condition may result from improper vehicle jumpstart battery connection or a reversed electrical connection.
- Upfitter-added electrical systems should tolerate a 24-volt vehicle jumpstart without degradation or damage to any electrical component.
- Short-term electrical overloads from stall or inrush currents without acting as a fuse or exhibiting internal component welding. (Exceptions are fuses and circuit breakers.)
- Normal vehicle shock or vibration. Newly installed components additionally must be compatible with the fluids normally found in or around the vehicle. For example, exterior components should be compatible with engine oil, automatic transmission fluid, ethylene glycol, window washer solvent and 5% salt water solutions. Interior components should be compatible with alcohol- or ammonia-based cleaners, vinyl plasticizers, soapy water and soft drinks.

Component Handling

Upfitters should exercise due care when handling, installing or storing Upfitter and/or OEM furnished electrical components. Unseen damage could result in a delayed failure of a component, a warranty claim, and a dissatisfied customer.

- Unprotected electrical components should not be stored in environments that would expose them to dust, dirt, water, grease, paint overspray, high humidity, etc.
- Care should be taken to assure that electrical components are not dropped or otherwise mishandled when being installed by Upfitters. Never install an obviously damaged part.
- Do not stack unprotected electrical components, such as radios and radio speakers, as they could easily sustain damage that may not be obvious to the installer.
- Do not allow foreign materials, such as metal chips or filings to become attached to either the cone or magnet of speakers. These and other contaminants can cause a buzz or rattle sound in the speaker

Electrical System Interfacing – Design Guidelines (continued)

OEM-furnished electrical components that are shipped in the dunnage box should remain in their protective packaging until they are needed for installation.

Component Precautions

🚫 GM does not recommend the installation of remote-start systems in GM trucks. This is due to the potential to detrimentally affect the function of the electrical and OBD II systems. Installation could also compromise the vehicle theft deterrent features and could result in a safety issue if the vehicle is started in gear.

RADIO FREQUENCY INTERFERENCE (RFI) PREVENTION

When delivered, General Motors vehicles comply with all current radio frequency interference (RFI) standards. It is important that Upfitters take all necessary precautions to maintain the RFI integrity of OEM systems and components. Additionally, Upfitters should install only signal receiving/transmitting devices that are compatible with both the OEM and Upfitter electrical systems.

The recommended guidelines are:

- Electrical devices should be designed or electrically isolated to prevent radio frequency interference to the OEM radio or Upfitter-installed radio, TV or DVD, etc. This is particularly important when adding inductive load devices such as mechanically or electronically commutated DC motors.
- Protect all Upfitter-added audio/video circuits from electrical ignition noise (from gasoline powered internal combustion engine) which may interfere with normal radio or TV reception.
- Use individual, clean (separate, single-function) circuits to power any added signal receiving/transmitting devices.
- To prevent possible electrical interference, never allow audio and video equipment power and signal circuits to share a common ground wire with other electrical equipment.
- Never route coaxial antenna cables adjacent to vehicle power circuit wires or within 8" of vehicle control modules.
- Make sure that added electrical or electronic devices that may emit electromagnetic radiation comply with SAE Standard J551 — Performance Levels and Methods or Measurement of Electromagnetic Radiation from Vehicles and Devices (30-1000 MHz).

Electrical System Interfacing – Design Guidelines (continued)

SERVICEABILITY

Serviceability is the relative ease with which a component or system can be diagnosed, removed, replaced, repaired or adjusted. Some vehicle upfitting decisions can adversely affect the serviceability of either the OEM- or Upfitter-installed electrical system, or both. Therefore, it is very important that Upfitters consider potential service requirements when designing electrical systems for conversion vehicles.

Service should be able to be accomplished:

- With minimum interference from unrelated parts
- In a minimum amount of time
- With reasonably priced parts and materials
- With standard hand tools and shop equipment
- Within the expertise of the average technician, with a minimum of special training
- Without damage to components or systems

Design Parameters

General Motors recommends the addition of the simplest electrical designs possible to allow for obvious, easy and accurate diagnostic procedures. Also, the design of an Upfitter electrical system should not adversely affect the serviceability of any OEM component and/or system. Another key design consideration is the most likely service facility and its capabilities.

The following guidelines will help the Upfitter to design a more serviceable electrical system:

- Design or install components and systems that can be easily serviced or replaced and are compatible with existing service industry capabilities.
- Design electrical system and components that eliminate multiple-part failures resulting from the failure of a single device.
- To reduce replacement costs, install components that can be rebuilt to original specifications.
- Install electrical components and systems capable of withstanding a 24-volt jump start without degradation or damage.
- Make sure that the electrical components or systems can withstand 14 volts DC applied in reverse polarity without degradation or damage.
- Limit the number of functions per fuse (one function per fuse, if possible). This will aid in diagnosing short circuits by subdividing circuitry.
- Provide easy service access to electrical components, such as connectors, crimp-and-seal and butt-splice sleeves, fuses, relays and circuit breakers. For connector service access, provide wiring service loops at all electrical component locations. Also allow for adequate tool access.
- Fasten wiring and electrical components to the vehicle so that they can be easily removed and reinstalled.
- Color code wire insulation consistently throughout the entire circuit length, including pigtails to individual components.
- Install readily available components whenever possible to reduce parts proliferation and replacement costs.

⚠ Service parts should be available for a minimum of 10 years after the vehicle has been sold to the customer.

Electrical System Interfacing – Design Guidelines (continued)

Diagnosability

Design and install electrical systems and components so that technicians can accurately determine the nature and location of a failure within a reasonable time frame and at a minimal cost.

Accessibility

The preferred electrical system designs provide for easy physical access to all electrical wiring, connections and components without major disassembly or interference from other vehicle components or systems. Avoid designs which can only be accessed by uncontrolled piercing of the wire insulation. GM strongly recommends against such practices as they can result in wire damage, corrosion, lost electrical integrity and eventual circuit failure.

Repairability/Replaceability

General Motors recommends the installation of systems and components that can be repaired within a minimum amount of time and a reasonable cost, using standard, readily available hand tools and shop equipment. The skill required for performing repair and replacement procedures should also fall within the average technician’s range of expertise.

Limited-Life Components

When considering limited-life components, such as light bulbs or fuses, choose readily available parts that the average customer can easily replace (i.e., within 5 minutes), using common, everyday tools. For Upfitter-added lighting devices, use standard 12-volt automotive type bulbs. Select fuses that are serviceable under industry standards. Both light bulbs and fuses should be easily obtained in the aftermarket and located for easy access within the vehicle (i.e. without major disassembly of vehicle systems, components, trim or hardware). See “Circuit Protection Guidelines” section.

FMVSS/CMVSS REQUIREMENTS

This section addresses the Federal Motor Vehicle Safety Standards (FMVSS) and Canadian Motor Vehicle Safety Standards (CMVSS) applicable to the OEM electrical system. Special Vehicle Manufacturers should not alter any OEM electrical component, assembly or system in a way that will either directly or indirectly result in the nonconformance of that component, assembly or system to any applicable FMVSS/CMVSS standard. This section contains information to help the Upfitter interpret FMVSS CMVSS standards that apply to electrical components, assemblies or systems in GM vehicles. In no way is this information intended to supplement or amend the specific requirements of any FVMSS/CMVSS standard. The Upfitter is responsible for obtaining copies of any and all FMVSS/CMVSS regulations that apply to the operations they perform and for interpreting how their operations will affect the vehicle’s compliance to these standards. Whenever an Upfitter alters any electrical component, assembly or system which requires FMVSS/CMVSS certification, adequate records must be generated and maintained on file, to document compliance to the applicable standard(s).

Electrical System Interfacing – Design Guidelines (continued)

FMVSS/CMVSS 108: Lamps, Reflective Devices and Associated Equipment

The vehicle, as shipped from GM to the Upfitter, is in compliance to this standard as outlined in the Incomplete Vehicle Document. Alterations to any component, assembly or system included in this standard requires the Upfitter to recertify compliance to the standard.

- The relocation and/or the substitution of the center high-mounted stop lamp (CHMSL) requires Upfitter certification to FMVSS 108 sections §5.1.1.27, §5.3.1.8, §5.4 and §5.54.
- Cutting (splicing) into any OEM wire that provides either an electrical power or ground circuit path, for any device listed in FMVSS 108, will require the Upfitter to certify that circuit continuity has not been interrupted to that device.

FMVSS/CMVSS 118: Power Operated Window Systems

The vehicle, as shipped from General Motors to the Upfitter, is in compliance to this standard as outlined in the Incomplete Vehicle Document. The Upfitter must not alter the power window electrical system in any way that will affect the way in which the system functions.

- This standard requires the ignition key, which controls the activation of the vehicle's engine, to be in the "ON," "START" or "ACCESSORY" position to enable the power-operated windows to be closed. Upfitters must not alter this function.

Electrical System – Installation Guidelines

WIRE HANDLING GUIDELINES

Proper handling will protect wire from damage which may otherwise occur during the conversion process. General Motors recommends the following precautions:

- Do not allow OEM or Upfitter wiring or connectors to hang or lay in areas where they can be damaged by subsequent assembly operations (i.e., welding flash, paint overspray, etc.). Temporarily fasten them out of the way or protect them until they are needed.
- Do not route wiring temporarily over, under, between or in doorjamb areas. Closing doors can result in damage to the wire.
- Do not tie wire assembly branches together to keep them out of the way. Knotting or tying wires together can result in damage.
- Keep wire assembly connectors in a protected location as the vehicle progresses through subsequent assembly stations.
- Store connectors in an accessible location, away from potentially damaging activities, until that point in the build sequence when they are mated.
- If required, temporarily fasten uncontrolled wiring assemblies to prevent them from dragging under or behind the vehicle.
- Establish and sequence assembly operations and work stations so that there is no employee competition for workspace, which can lead to missed operations.
- Do not allow electrical components to hang from wiring leads. The weight of a component can damage the wire or cause complete or partial disconnect.
- Implement practices to protect Upfitter and OEM wiring and connectors that lay temporarily on the floor from damage which may result from normal operator activities. Do not walk, step on or lay heavy objects on wiring.

WIRE ROUTING GUIDELINES

Proper wire routing is essential to the electrical system’s long-term reliability. Improper wire routing can lead to many different electrical malfunctions and costly repairs. Following the simple guidelines in this section can help the Upfitter to produce a more trouble-free electrical system. GM strongly recommends that visual graphic displays depicting Upfitter wiring routings be prominently displayed at all electrical work stations to promote consistency in installation processes. GM also recommends that OEM wiring not be rerouted or relocated within the vehicle unless it would become vulnerable to damage due to Upfitter assembly operations.

Electrical System – Installation Guidelines (continued)

Location

- Route wiring so that it does not come into contact with any of the vehicle's moving parts (e.g., seat-adjuster and power sofa mechanisms, sunroof mechanisms, brake and clutch pedals, etc.).
- Be sure to allow a distance of at least 125.0 mm (5 inches) between the wiring and any source of radiant heat. Heat can deteriorate wiring insulation to the point where breaks in the insulation can occur, this in turn can result in arcing and a short circuit condition. Examples of radiant heat sources are exhaust manifolds and pipes, catalytic converters, EGR valves, light bulbs and electronic device heat sinks.
- Where possible and practical, install wiring inside the vehicle. If exterior wiring is necessary, make sure to adequately protect it from road hazards.
- As much as possible, route wires in and through areas where they are least vulnerable to damage from subsequent assembly operations (e.g., blindly driven trim attaching screws). If wiring must be routed through vulnerable areas, take great care to sufficiently protect the wiring.
- Route wiring away from potentially damaging vehicle surfaces, such as sharp or abrasive objects, raw sheet metal holes, sharp metal flanges, spot-weld flash points, etc.
- Route wiring located in the Instrument Panel area so that it doesn't hang down around pedals or in areas that can be contacted by either driver or passenger foot movements.
- Upfitter underhood wiring, that is routed near the OEM battery, should be kept a minimum of 75.0 mm (3 inches) away from the battery vent holes as caustic fumes emitted from these vent holes can have a deteriorating effect on wiring insulation.
- Route Upfitter wiring in areas that can be easily accessed for service and repair.
- When routing wiring to connectors on electrical/ electronic modules or similar devices, it is recommended that a water drip loop be incorporated in the wire just before it connects to the module. This will prevent water that may have accidentally entered the vehicle from tracking along the wire and entering the module.
- When routing wiring through a grommet from the outside to the inside of the vehicle, it is recommended that a water drip loop be incorporated in the wiring just before it enters the grommet. This will prevent water from tracking along the wire and entering the interior of the vehicle through the grommet. See "Wire Harness Assembly Guidelines" and "Serviceability" under the "Electrical System Design Guidelines" section for additional recommendations regarding wiring location.

Tension

Any strain exerted on the wiring between two fixed points that is greater than the weight of the wiring itself is referred to as "tension." General Motors recommends routing wire to avoid tension and allow some, but not excessive, slack between fixed attached points. Examples of fixed attaching points are clips, clamps, connectors and grommets.

Electrical System – Installation Guidelines (continued)

Accessibility

Upfitter-installed wiring connections should be accessible during vehicle assembly operations. Recommended locations are those where the wiring connectors are completely visible and easily accessed by the operator. Whenever possible, avoid "blind" connections which prevent the operator from seeing the connection and using both hands to make the connection.

Appearance

All Upfitter-added wiring, in the vehicle passenger compartment, should be visually hidden from the customer's normal line of sight.

The appearance of visually exposed wiring in the engine compartment of GM vehicles is important in that it can convey either a positive or negative quality connotation. GM recommends the following guidelines be followed when Upfitters add visually exposed wiring in the engine compartment of GM vehicles:

- Every effort should be made to hide all wiring from the normal line of sight of the customer.
- All wiring that cannot be hidden should be covered with black colored conduit or tape.
- All visually exposed electrical connectors, TPA and CPA devices should be black or dark gray in color.
- Every effort should be made to route visually exposed electrical wiring either parallel to or perpendicular to engine and/or body sheet metal lines.
- Identification tape, attached to wiring and/or connectors, should be removed prior to shipping the vehicle, if it will be in the customer's normal line of sight.

WIRE FASTENING GUIDELINES

All Upfitter-added wiring should be positively fastened to prevent pinching, entrapment, misrouting or other conditions that could lead to potential electrical problems. Use ties, clips, clamps or other fasteners to secure wires in their intended locations, away from areas that would expose them to damage during assembly operations.

Additional recommendations are:

- Develop and establish procedures that ensure the correct and consistent selection, use, quantity and placement of wiring fasteners within the vehicle.
- Use "stick-on" wiring clips capable of maintaining adhesive qualities for a minimum of 10 years, over a temperature range of –40°C (40°F) to +85°C (185°F).
- Apply stick-on wiring clips only to surfaces that are clean and free from debris. This will assure that their adhesive qualities are not compromised.

Electrical System – Installation Guidelines (continued)

- GM strongly recommends against the practice of using tape as the primary method of securing wires to the body sheet metal. Doing so will generally result in an unacceptable process due to uncontrolled production variations. If tape is used as an auxiliary or secondary means of attachment, it must be capable of maintaining its adhesive qualities for a minimum of ten years, over a temperature range of –40°C (40°F) to +85°C (185°F) and should be applied only to surfaces that are clean, dry and free of dirt or other contaminants that could prevent permanent adhesion.
- When using profile conduit to route and retain the wiring within the vehicle, positively fasten the conduit — not the wiring — to the vehicle structure.
- Make sure to securely fasten and insulate all Upfitter-adding wiring from all hard vehicle surfaces. This will prevent squeaks and rattles during normal vehicle operation. Taping wires to the body structure, to prevent squeaks and rattles, is not recommended.

WIRE AND ELECTRICAL COMPONENT PROTECTION GUIDELINES

Protecting wiring in a vehicle with some type of protective device reduces the possibility of several common electrical problems. For example, when a wire is cut, it is usually because it was not properly protected from a hostile surface. Similarly, when a wire is chafed or burned, it is common to find that it was rubbing against a sharp object or located too close to a heat source.

Protective Devices

Sometimes it is necessary to route unprotected wiring through a raw metal hole. In such cases, the hole should be edged with either a wiring grommet or hole edge protector. Taping the raw metal edges will not adequately protect the wiring.

Wiring grommets and wiring pass-through devices, used to channel wiring between the passenger compartment and the vehicle's exterior must seal both the hole in the sheet metal and the area around the wire. This prevents moisture and noxious fumes from entering the vehicle. Grommet mounting surfaces should be flat and free of contaminants that could prevent a positive seal.

When it is impossible to avoid routing wire near a radiant heat source, use heat shields, heat reflective tape and/or heat-retardant conduit to protect the wiring. See "Wire Routing Guidelines" section. Exterior wiring (i.e., in the lower half of the engine compartment, exterior wheel wells and underbody areas) is highly vulnerable to damage from stones, sand, dirt, water and road debris. To protect wiring in these areas, install splash or debris shields. See "Wire Routing Guidelines" section.

Wire paths, especially vehicle floor areas, should be clean and free of foreign objects and debris (i.e., metal shavings from cutting and drilling operations, lost screws, etc.). If it is not possible to thoroughly clean the vehicle prior to wiring, use a hard-surfaced conduit or other means to protect the wiring.

Externally mounted electrical devices such as opera lamps, relays, fuse holders, circuit breakers, etc., should be environmentally sealed or incorporate a sealing gasket. This will prevent potential corrosion of electrical contacts and the subsequent electrical failure of the device.

Electrical System – Installation Guidelines (continued)

Upfitter-added relays, switches, electric/electronic modules and/or similar devices, that maintain a "B+" potential, should be mounted and/or shielded in such a way as to prevent water from accidently entering the device. Water entry could cause the device to short circuit internally and result in a thermal incident. GM recommends that these types of devices be mounted with their terminals facing downward and that the connecting wiring harness incorporate a water drip loop.

GROUNDING GUIDELINES

- Proper grounding is important for quality electrical systems and protection from unwanted electrical feedback.
- Use GM-provided ground studs or connectors when possible. Refer to the appropriate Body Builder Manual for locations of these studs and connectors.
- Choose ground fasteners (studs, ring terminals, etc.) that are plated for corrosion resistance. Make sure that they are compatible with the ground material to minimize the possibility of galvanic corrosion. Ring terminals should have an anti-rotation feature. (See Figure 37).
- Do not use rivets or sheet metal screws to establish a ground connection.
- Make sure that all grounding surfaces are clean and free of paint, sealers and non-conductive materials.
- Make sure that all grounding surfaces are clean and free of paint, sealers and non-conductive materials.
- Avoid stacking ring terminals if possible. If stacking cannot be avoided, no more than two ring terminals should be stacked at any one location.
- As far as possible, locate ground attachments such that they are readily accessible to the service community.

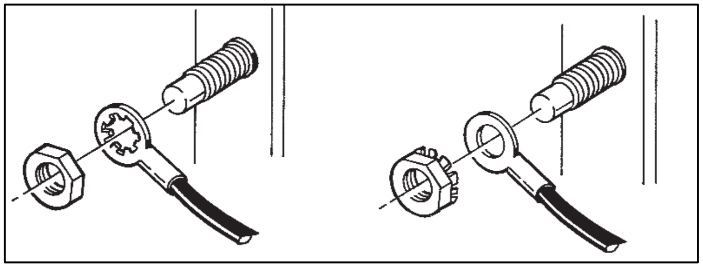


Figure 37

ISOLATION OF "CLEAN" AND "DIRTY" ELECTRICAL GROUNDS

For a circuit to power an electrical load it is necessary that there is a return path to ground from the load. In automotive applications, this ground is equivalent to the negative terminal on the battery. Depending on the type of load, the ground can be considered as either a "clean" or a "dirty" ground. If clean grounds are combined with dirty grounds, the loads with the clean grounds may not function correctly due to voltage and current transients from the dirty grounds. Also, the voltage drop from the dirty load can induce noise in the signals read by electronic modules. Serial data devices which use clean grounds may not work properly due to voltage offsets from dirty grounds. It is important to adequately isolate clean and dirty grounds in order minimize these effects.

Electrical System – Installation Guidelines (continued)

Clean Grounds

- Clean grounds can be characterized by the following:
- DC resistive loads with steady state currents less than 2 amps.
- Speed sensors and other generators of variable frequency signals feeding high impedance resistive loads (less than 500 ohms).
- Pulse-width-modulated (PWM) resistive loads, with peak “on” currents less than 2 amps.
- DC lamp loads, with steady state currents less than 1 amp.
- PWM lamp loads, with peak “on” currents < 1 amp (not including inrush current).
- Serial data signals.

Dirty Grounds

- Resistive or lamp loads falling outside the “clean” boundaries described above.
- Any load that has either a capacitive or inductive component that would cause either “turn-on” transients (inrush currents), or “turn-off” transients (voltage spikes).
- Motor loads (except for small devices such as display stepper motors).
- Solenoid loads.

WELD NUTS, WELD STUDS, SCREW/WASHERS AND TERMINALS USED FOR GROUNDING

Weld Nuts

An M6 x 1 unthreaded weld nut and M6 x 1 x 20 hex head thread-rolling screw with flat washer (Taptite™ or equivalent) is recommended for body electrical grounding. These components are ideal for the welding and assembly processes, and provide a reliable ground path.

A good weld (drawn Arc type) is made between the fastener and the base metal.

- The conductive contact area between the threads of the bolt and the nut must be adequate.
- There is enough joint clamp load in the joint to prevent loosening and loss of the conductive ground path.
- The proper weld schedules must be used.
- The grip length of the joint must be adequate to maintain clamp load integrity.

If a weld nut cannot be used, a surface weld stud with a loose nut should be used. The following conditions may prevent the use of a weld nut:

- Water or exhaust may intrude through through holes.
- Panel back side has no clearance for the weld nut.
- Panel back side has no access for nut attachment.

Electrical System – Installation Guidelines (continued)

Weld Studs

The weld stud consists of an M6 x 1.0 x 21 stud with an M-Point coated with a conductive hexavalent chrome-free finish. The nut is part of the stud assembly, eliminating masking the threads and base of the stud and nut to prevent being coated by paint. The weld stud also has an anti-rotation feature which prevents the terminal from turning when tightened. Use weld studs only when a weld nut cannot be used. The preferred grounding method is the weld nut.

Washer

- The washer should have nominal outer diameter of 17 mm and a minimum thickness of 2 mm.

- The washer must be located under the screw's head.

Ground Terminal

A M6 thread-forming bolt with an unthreaded weld nut and an anti-rotation tab that fits into a hole in the sheet metal is the recommended ground terminal. This terminal should be able to withstand a 10 Nm dynamic torque without deforming the tab. A maximum of two terminals should be stacked in one location. The second terminal does not have a tab and should be located between the tabbed terminal and the body. If one wire is a larger gage than the other, the larger gage wire should be placed in the tabbed terminal.

Electrical System – OEM Components

OEM COMPONENT LOCATION GUIDELINES

Upfitters should never relocate OEM electrical components such as batteries, fuse centers, junction blocks, relays, ECMs, PCMs, VCMs, electronic modules, ground screws, etc., for the sake of facilitating their build process. Approval should be sought from an Upfitter Integration team member in the event that an Upfitter feels there is an absolute necessity to relocate one of these components.

Safety Systems:

Vehicle safety system components should never be removed and/or relocated without first contacting General Motors Upfitter Integration group (www.gmupfitter.com). Be advised that the components for the following systems…Air Bag, Anti-lock Braking, Collision Avoidance, Obstacle Detection Lane Departure and Blind Spot Warning cannot be relocated as the systems are calibrated to their location within and to the vehicle.

Electrical Components (non-safety system related)

When relocating electrical components careful consideration needs to be given as to environmental conditions of the new location. Such things such as moisture, temperature, electromagnetic interference, signal interference/impediment

Under-hood/Vehicle:

When relocating components outside the passenger compartment of the vehicle steps to protect the device/component from high heat sources such exhaust system, engine block, cooling system and their associated parts/sub-assemblies.

Consideration to the possibility of water/moisture intrusion must also be given, many outside areas of the vehicle are often subject to water splash and/or spray so the components must be protected by a water tight housing with proper weather protected connector and seal assemblies.

Consideration to any and all moving parts/components is required when selecting a new location.

Under-dash:

Components being considered for relocation inside of the passenger component need to have the same environmental considerations given as to the selected location. Components to be mounted under dash/above the driver/operator foot controls must secured so as to not impose a risk of dislodging and impeding the operation of any of the vehicles foot controls. Under dash mounting must also not impede the operation of any of the vehicles sub-systems.

Doors:

When relocating components within the doors consideration to moving parts and environment. When considering a new location for a components be aware of the travel path of the moving window and its components. Also being sure not to impact any of the door latching/release systems. Additionally reinstallation of the door’s water deflection system/shields is required to prevent water intrusion inside the vehicle. Electrical system components should never be relocated to the “wet” side of the water deflection system. To prevent water intrusion into components inside of the door, connector interfaces should always be located in a downward orientation. It is also suggested that wire harnesses be routed with a drip loop near or at the device whenever possible.

Electrical System – OEM Components (continued)

Under Seats:

When relocating components under or near the seats consideration to any and all moving parts and environment must be giving. When considering a new location for a components be aware of the travel path of the moving seat and its components. Also being sure not to impact any of the seat's latching/release systems. Many front driver and passenger seats have integrated safety components that too must not be interfered with as well. Consideration to the seat belt system and its moving and latching system must also be given.

Rear Stowage Areas:

When mounting or location electrical components in the rear stowage area of the vehicle consideration to any and all moving parts and environment must be giving. Additionally once again environment must consider when mounting or locating a device in this area to the "drip zone" of water/moisture dripping off the rear stowage area enclosure. Be sure that when the enclosure is opened that any water or moisture that may be on the enclosure won't drip onto the mount device/components.

General Recommendation:

Lastly, always give consideration to any and all possible impacts to the vehicle's operator and occupants when adding or relocating electrical devices.

Repairing Damaged Wire Insulation

If the wire insulation has been chafed, or broken, enough to show the conductive portion of the wire, and the wire is not damaged, determine the length of insulation that needs to be repaired. If the repair is less than 280 mm (11 in), cut the wire within the damaged area. Then slide the appropriate heat shrink tubing (listed below) over the wire, and repair the wire by splicing the wires together. Refer to Splicing Copper Wire Using Splice Sleeves in Wire to Wire Repair. Once the wire is spliced together slide heat shrink tubing over the damaged area and apply heat to seal the repaired wire.

If the wire is damaged, or the damaged area is larger than 280 mm (11 in), then replace the damaged wire by splicing in a new section of wire. Refer to Splicing Copper Wire Using Splice Sleeves in Wire to Wire Repair.

Heat Shrink Tubing Selection

GM Part Number	Diameter		Description	Color	Length	
	Metric	English			Metric	English
12355010	3.2 mm	0.125 in	Tubing, Shrink 1/8	Black	305 mm	12 in
12355003	9.5 mm	0.375 in	Tubing, Shrink 3/8	Black	305 mm	12 in
12355005	12.7 mm	0.5 in	Tubing, Shrink 1/2	Black	305 mm	12 in
12355011	19.1 mm	0.75 in	Tubing, Shrink 3/4	Black	305 mm	12 in
12355008	25.4 mm	1.0 in	Tubing, Shrink 1.00	Black	305 mm	12 in

Wire Size Conversion

Metric Wire Sizes (mm 2)	AWG Sizes
0.13	26
0.21	24
0.35	22
0.5	20
0.8	18
1.31	16
2.09	14
3.31	12
5.27	10
8.37	8
13.3	6
21.2	4
33.6	2
Metric Wire Sizes (mm 2)	**AWG Sizes**
53.5	1/0

Splicing Inline Harness Diodes

Many vehicle electrical systems use a diode to isolate circuits and protect the components from voltage spikes. When installing a new diode use the following procedure.

1. Open the harness.
    - If the harness is taped, remove the tape.
    - To avoid wiring insulation damage, use a sewing seam ripper (available from sewing supply stores) in order to cut open the harness.
    - If the harness has a black plastic conduit, pull out the diode.

2. If the diode is taped to the harness, remove all of the tape.

3. Check and record the current flow direction and orientation of diode.

4. Remove the inoperative diode from the harness with a suitable soldering tool.

    Note: If the diode is located next to a connector terminal remove the terminal(s) from the connector to prevent damage from the soldering tool.

5. Carefully strip away a section of insulation next to the old soldered portion of the wire(s). Do not remove any more than is needed to attach the new diode.

6. Check current flow direction of the new diode, being sure to install the diode with correct bias. Reference the appropriate service manual wiring schematic to obtain the correct diode installation position.

7. Attach the new diode to the wire(s) using 60/40 rosin core solder. Before soldering attach some heat sinks (aluminum alligator clips) across the diode wire ends to protect the diode from excessive heat. Follow the manufacturer's instruction for the soldering equipment.

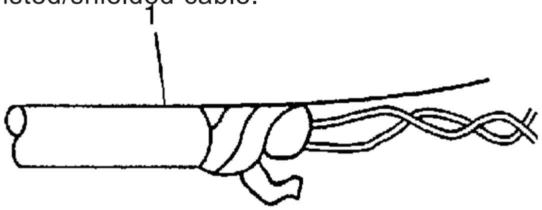
8. Reinstall terminal(s) into the connector body if previously removed.

    Note: To prevent shorts to ground and water intrusion, completely cover all exposed wire and diode attachment points with tape.

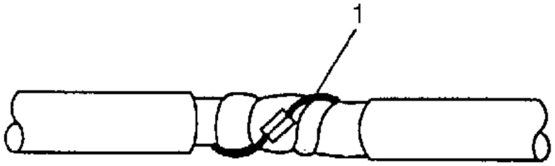
9. Tape the diode to the harness or connector using electrical tape.

Splicing Twisted or Shielded Cable

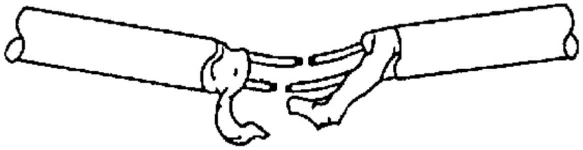
Twisted/shielded cable is used in order to protect wiring from electrical noise. Two-conductor cable of this construction is used between the radio and the Delco-Bose® speaker/amplifier units and other applications where low level, sensitive signals must be carried. Follow the instructions below in order to repair the twisted/shielded cable.



1. Remove the outer jacket (1). Use care not to cut into the drain wire of the mylar tape.
2. Unwrap the tape. Do not remove the tape. Use the tape in order to rewrap the twisted conductors after the splice is made.



3. Prepare the splice. Untwist the conductors and follow the instructions for Splicing Copper Wire Using Splice Sleeves in [Wire to Wire Repair](). Staggering the splices by 65 mm (2.5 in) is recommended.



Note: Apply the mylar tape with the aluminum side inward. This ensures good electrical contact with the drain wire.

Splicing Twisted or Shielded Cable (continued)

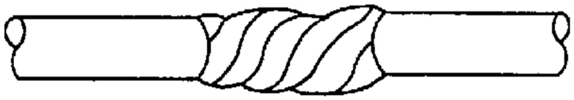
4. Re-assemble the cable.

   - Rewrap the conductors with the mylar tape. If the mylar tape is damaged, use 3M product AL-36FR to replace the damaged mylar tape.

   - Use caution not to wrap the drain wire in the tape (1).

   - Follow the splicing instructions for copper wire and splice the drain wire.

   - Wrap the drain wire around the conductors and tape with electrical tape to replace the outer insulation.



5. Tape over the entire cable. Use a winding motion when you apply the tape.

Wire to Wire Repair

Danger: In order to reduce the risk of personal injury, loss of high voltage isolation to ground and higher system impedance, do not attempt to repair any HV wiring, connector, or terminal that is damaged. High voltage coaxial type cables are not repairable. Never attempt to repair a coaxial type cable. The entire cable/harness or component must be replaced. In order to maintain system integrity and personal safety, never attempt to repair any high voltage wiring, cables, or terminals. Performing this procedure on high voltage circuits may result in serious injury or death.
Note: If the wiring harness internal to the transmission is damaged, the wiring harness must be replaced. The use of splice sleeves in an attempt to repair the internal transmission wires, connectors, or terminals could result in performance issues.

Note: Do not splice wires in Door Harness Grommets.

Note: The DuraSeal splice sleeves have the following 2 critical features:

- A special heat shrink sleeve environmentally seals the splice. The heat shrink sleeve contains a sealing adhesive inside.
- A cross hatched (knurled) core crimp provides the necessary low resistance contact integrity for these sensitive, low energy circuits.

Use only DuraSeal splice sleeves to form a one-to-one splice on all types of insulation except high voltage and specialty cables. Use DuraSeal splice sleeves where there are special requirements such as moisture sealing. Follow the instructions below in order to splice copper wire using DuraSeal splice sleeves.

Splice Sleeve Selection

	Crimp Tool Nest Color		
Splice Sleeve Color	**3 Crimp Nests**	**4 Crimp Nests**	**Wire Gauge mm^2 / (AWG)**
Salmon (Yellow-Pink) 19300089	Red (1) or Red/Green (1)	Red (2)	0.22–0.8/(18–26)
Blue 19168447	Blue (2)	Blue (3)	1.0–2.0/(14–16)
Yellow 19168448	Yellow (3)	Yellow (4)	3.0–5.0/(10–12)

Note: You must perform the following procedures in the listed order. Repeat the procedure if any wire strands are damaged. You must obtain a clean strip with all of the wire strands intact.

1. Open the harness by removing any tape:
    - Use a sewing seam ripper, available from sewing supply stores, in order to cut open the harness in order to avoid wire insulation damage.
    - Use the DuraSeal splice sleeves on all types of insulation except Tefzel and coaxial.
    - Do not use the crimp and DuraSeal splice sleeve to form a splice with more than 2 wires coming together.

2. Cut as little wire off the harness as possible. You may need the extra length of wire in order to change the location of a splice.

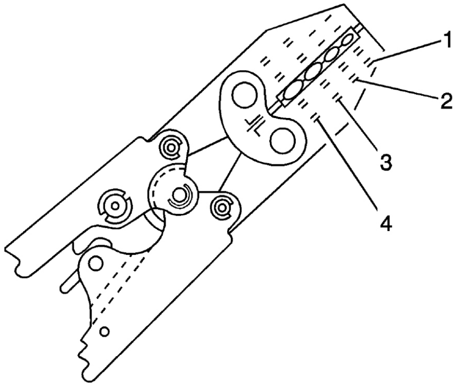
Adjust splice locations so that each splice is at least 40 mm (1.5 in) away from the other splices, harness branches, or connectors.

Splice Sleeve Selection (continued)

3. Strip the insulation:
   - When adding a length of wire to the existing harness, use the same size wire as the original wire.
   - Perform one of the following items in order to find the correct wire size:
     - Find the wire on the schematic and convert to regional wiring gauge size.
     - If you are unsure of the wire size, begin with the largest opening in the wire stripper and work down until achieving a clean strip of the insulation.
   - Strip approximately 5.0 mm (0.20 in) of insulation from each wire to be spliced.
   - Do not nick or cut any of the strands. Inspect the stripped wire for nicks or cut strands.
   - If the wire is damaged, repeat this procedure after removing the damaged section.

4. For high temperature wiring, slide a section of high temperature SCT1 shrink tubing down the length of wire to be spliced. Ensure that the shrink tubing will not interfere with the splice procedure.

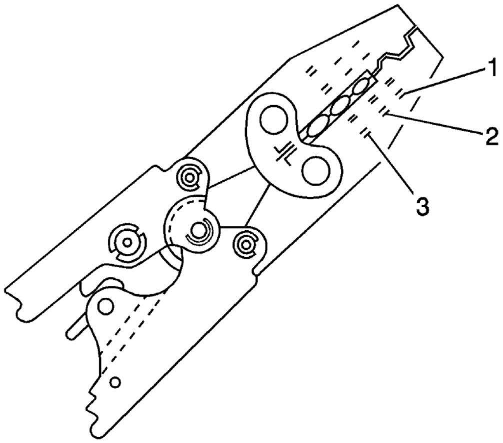
5. Select the proper DuraSeal splice sleeve according to the wire size. Refer to the above table at the beginning of the repair procedure for the color coding of the DuraSeal splice sleeves and the crimp tool nests.



6. Most splice sleeve crimping tool have several crimp nests. The largest crimp nest may be marked for crimping 10 and 12 gauge wires and the next for crimping 14 and 16 gauge wires, then for 18 and 20 gauge wires and possibly down to 22 to 26 gauge wires. The crimp nests are referenced in the table (farther above) under the crimp tool nest color.

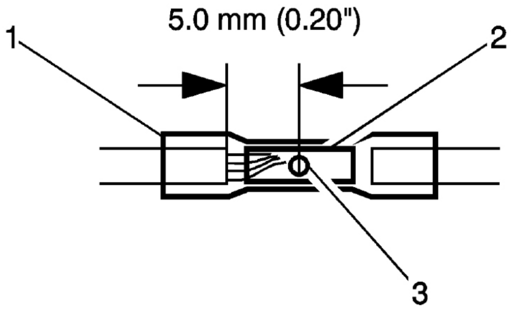
Note: The GM special tool ***EL-38125-10 splice sleeve crimping tool*** is illustrated above and the 4 crimp nests are referenced in the 'Splice Sleeve Selection' table above.

Splice Sleeve Selection (continued)



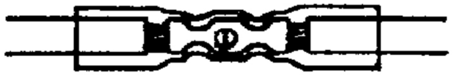
7. The ***J-38125-8 splice sleeve crimping tool*** has three crimp nests. The largest crimp nest (3) is used for crimping 10 and 12 gauge wires. The second largest crimp nest (2) is used for crimping 14 and 16 gauge wires. The smallest crimp nest (1) is used for crimping 18 to 20 gauge wires. The crimp nests are referenced in the table (farther above) under the crimp tool nest color.

8. Use the splice sleeve crimp tool in order to position the DuraSeal splice sleeve in the proper color nest of the splice sleeve crimp tool. For the four crimp nest tool, use the three largest crimp nests to crimp the splice sleeves. For the three crimp nest tool, use all three crimp nests to crimp the splice sleeves. Use the four and three crimp tool diagrams (above) and the table (farther above) to match the splice sleeve with the correct crimp nest. The crimp tool diagram callout numbers match the numbers in the table (under crimp tool nest color).



9. Place the DuraSeal splice sleeve in the nest. Ensure that the crimp falls midway between the end of the barrel and the stop. The sleeve has a stop (3) in the middle of the barrel (2) in order to prevent the wire (1) from going further. Close the hand crimper handles slightly in order to firmly hold the DuraSeal splice sleeve in the proper nest.

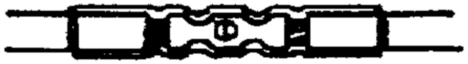
Splice Sleeve Selection (continued)



10. Insert the wire into the splice sleeve barrel until the wire hits the barrel stop. Refer to Folded-Over Wire Repair for splicing wires of 0.35 mm or less (22, 24, 26 gauge sizes) and for splicing wires of different gauges.

11. Tightly close the handles of the crimp tool until the crimper handles open when released.

The crimper handles will not open until you apply the proper amount of pressure to the DuraSeal splice sleeve. Repeat steps 4 and 6 for the opposite end of the splice.



12. Using the heat torch, apply heat to the crimped area of the barrel.

13. Start in the middle and gradually move the heat barrel to the open ends of the tubing:

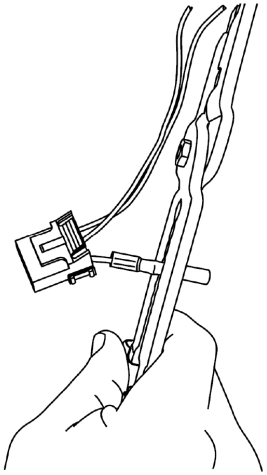
- The tubing will shrink completely as the heat is moved along the insulation.

- A small amount of sealant will come out of the end of the tubing when sufficient shrinkage is achieved.

Weatherpack™ Wiring Repair

Note: Some replacement pigtail connectors may be delivered without the terminated leads installed into the connector. For Weatherpack™ connectors, all terminated leads included in the package should to be installed into the connector. If the connector end view shows that a terminal is not occupied, the extra terminated lead(s) need to be installed and the end(s) sealed using a DuraSeal splice sleeve and taped back into the harness.

1.Insert the wire into the splice sleeve barrel until the wire hits the barrel stop. Refer to Folded-Over Wire Repair for splicing wires of 0.35 mm or less (22, 24, 26 gauge sizes) and for splicing wires of different gauges.

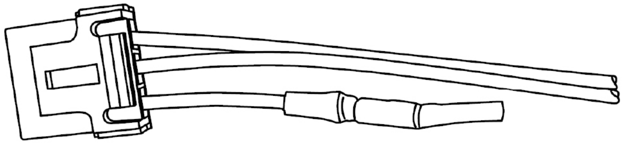


2. Tightly close the handles of the crimp tool until the crimper handles open when released.

The crimper handles will not open until you apply the proper amount of pressure to the DuraSeal splice sleeve. Holding the DuraSEAL with one hand gently tug on the wire to ensure it is crimped in the DuraSeal.

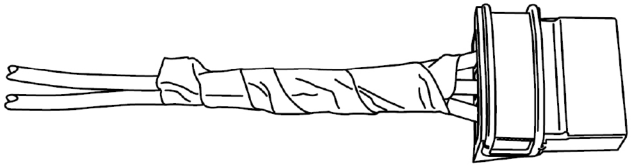
3. Using the heat torch, apply heat to the crimped area of the barrel.

Weatherpack™ Wiring Repair (continued)



4. Start in the middle and gradually move the heat barrel to the open ends of the tubing:

    - The tubing will shrink completely as the heat is moved along the insulation.
    - A small amount of sealant will come out of the end of the tubing when sufficient shrinkage is achieved.



5. Tape the extra terminated lead(s) back into the harness.

Connector Position Assurance Locks

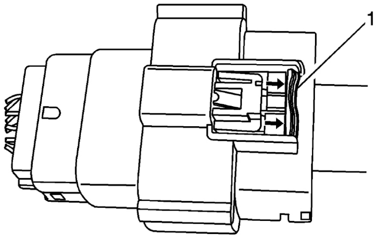
The connector position assurance (CPA) is a small plastic insert that fits through the locking tabs of the connector. CPAs are used in various connectors throughout the vehicle. The CPA ensures that the connector halves cannot vibrate apart. You must have the CPA in place in order to ensure good contact between the mating terminals of the connector.

Terminal Position Assurance Locks

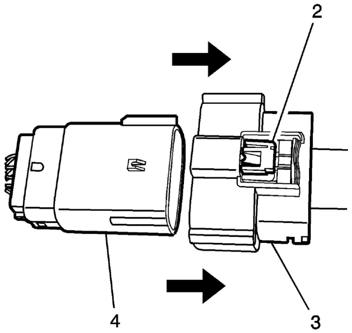
The terminal position assurance (TPA) insert resembles the plastic combs used in the control module connectors. The TPA keeps the terminal securely seated in the connector body. Do not remove the TPA from the connector body unless you remove a terminal for replacement. If the TPA is removed, be sure to reinstall it before reconnecting the connector.

CPA Connectors

Connector Removal Procedure



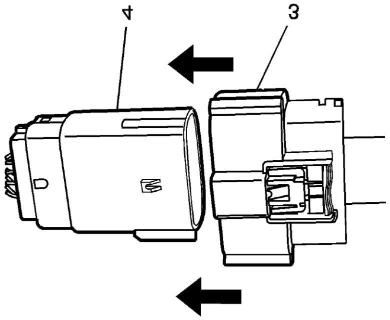
1. Pull out the red CPA (Connector Position Assurance) [1] on the female chassis harness signal connector.



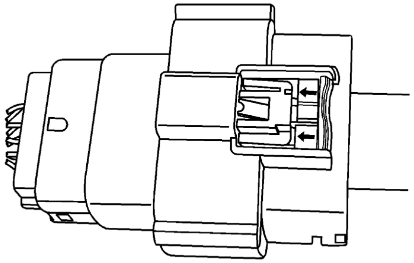
2. Depress the connector locking tab (pump arm) [2] of this connector [3] to allow it to disengage from the male pigtail connector [4].

3. Pull on the female connector [3] to separate it from the male connector [4].

Connector Installation Procedure



1. Align the female connector [3] to the male connector [4] locking feature and push them together until fully engaged.

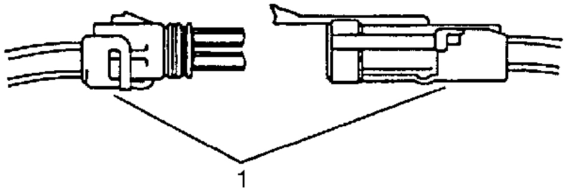


2. Push in the red CPA (Connector Position Assurance) on the female chassis harness signal connector to lock them securely.

Delphi Connectors (Weather Pack®)

Terminal Removal Procedure

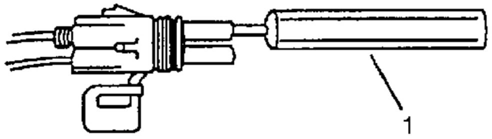
The following is the proper procedure for the repair of Weather Pack® Connectors.

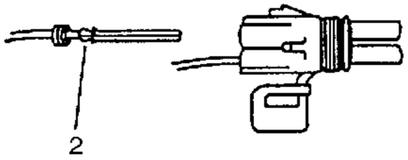


1. Separate the connector halves (1).

2. Open the secondary lock. A secondary lock aids in terminal retention and is usually molded to the connector (1).

3. Grasp the wire and push the terminal to the forward most position. Hold the wire in this position.





4. Insert the **Weather Pack® terminal removal tool J-38125-10A** into the front (mating end) of the connector cavity until it rests on the cavity shoulder (1).

5. Gently pull on the wire to remove the terminal through the back of the connector (2).

Note: Never use force to remove a terminal from a connector.

Delphi Connectors (Weather Pack®) (continued)

6. Inspect the terminal and connector for damage. Repair as necessary. Refer to Repairing Connector Terminals.

7. Reform the lock tang (2) and reset terminal in connector body.

8. Close secondary locks and join connector halves.

9. Verify that circuit is complete and working satisfactorily.

10. Perform system check.

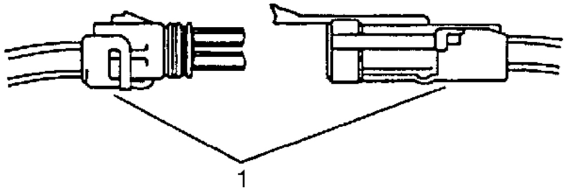
11. Repair the terminal by following the Repairing Connector Terminals procedure.
I
12. nsert the repaired terminal back into the cavity. Repeat the diagnostic procedure to verify the repair and reconnect the connector bodies.

Delphi Connectors (Push To Seat)

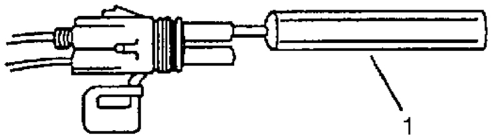
Terminal Removal Procedure

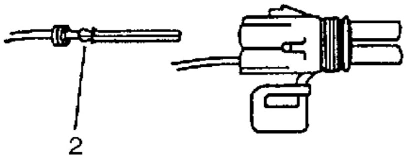
Follow the steps below in order to repair push to seat connectors.

1. Remove the terminal position assurance (TPA) device, the connector position assurance (CPA) device, and/or the secondary lock.



2. Separate the connector halves (1).

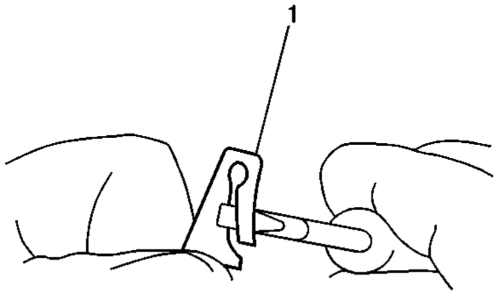




3. Use the proper pick or removal tool (1) in order to release the terminal.

4. Gently pull the cable and the terminal (2) out of the back of the connector.

Delphi Connectors (Push To Seat) (continued)



5. Re-form the locking device if you are going to reuse the terminal (1).

6. Repair the terminal by following the Repairing Connector Terminals procedure.

7. Insert the repaired terminal back into the cavity. Repeat the diagnostic procedure to verify the repair and reconnect the connector bodies.

Terminal Insertion Procedure

1. In order to reuse a terminal or lead assembly, refer to Wiring Repairs.

2. Ensure that the cable seal is kept on the terminal side of the splice.

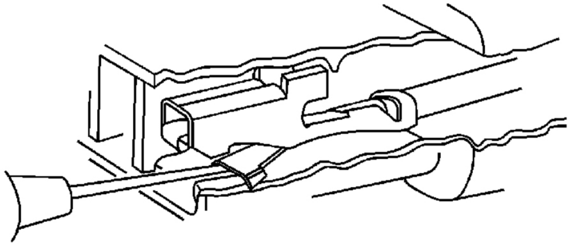
3. Insert the lead from the back until it catches.

4. Install the TPA, CPA, and/or the secondary locks.

Delphi Connectors (Pull To Seat)

Terminal Removal Procedure

If the terminal is visibly damaged or is suspected of having a faulty connection, the terminal should be replaced.



Follow the steps below in order to repair pull-to-seat connectors:

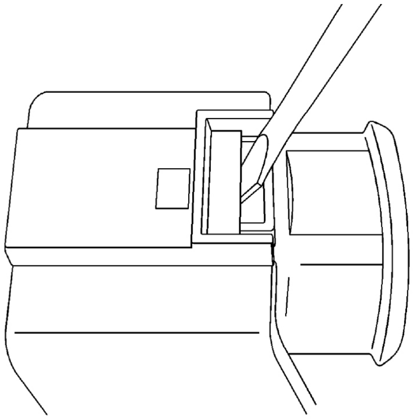
1. Remove the connector position assurance (CPA) device and/or the secondary lock.
2. Disconnect the connector from the component or separate the connectors for in-line connectors.
3. Remove the terminal position assurance (TPA) device.
4. Review the connector end view to determine the proper test probe and release tool.
5. Insert the release tool into the front of the connector body.
6. Grasp the wire at the back of the connector body and gently push the terminal out the front of the connector body.
7. Repair the terminal by following the Repairing Connector Terminals procedure.
8. Insert the repaired terminal back into the cavity. Repeat the diagnostic procedure to verify the repair and reconnect the connector bodies.

Terminal Insertion Procedure

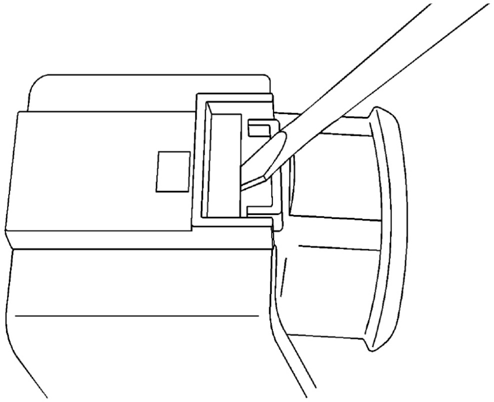
1. Align the terminal and pull the wire from the back of the connector in order to seat the terminal.
2. If the connector is outside of the passenger compartment, apply dielectric grease to the connector.
3. Install the TPA, CPA, and/or the secondary locks.

Delphi Connectors (Steering Gear)

Removal Procedure



1. Use a small flat-bladed tool to release the locking tab on the connector.

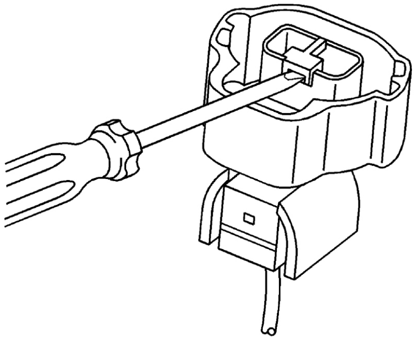


2. Push down the locking tab to release the connector. The small flat-bladed tool may need to be pushed down and angled back slightly to depress the locking tab. Pull on the connector body while releasing the locking tab to disconnect the connector.

Yazaki Connectors (2-Way)

Terminal Removal Procedure

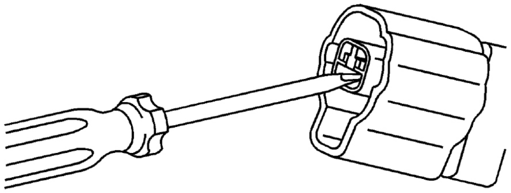
1. Disconnect the connector from the component.



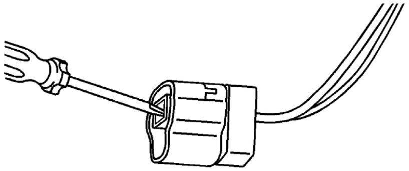
2. Insert a small flat-blade tool in the slot below the front loaded terminal position assurance (TPA) and pry up.

3. Remove the TPA by pulling it out of the connector.

4. Push the wire side of the terminal that is being removed toward the connector and hold it in position.



5. Insert the **J-38125-553** on a slight upward angle into the cavity below the terminal to be removed. Ensure that the pointed on the end of the tool is facing the bottom of the terminal and it stays in contact with the terminal until it stops on the plastic terminal retainer.



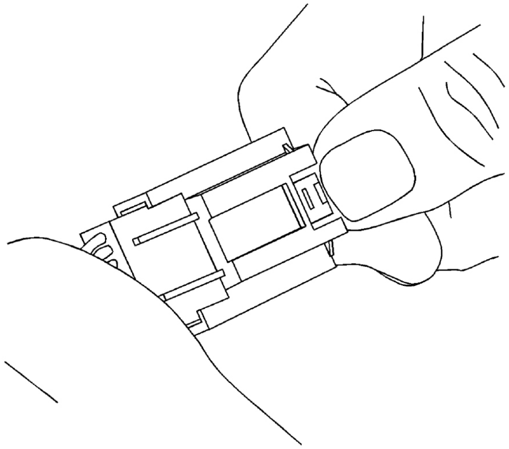
6. Gently pry the plastic terminal retainer down and carefully pull the terminal out of the connector. Always remember never use force when pulling a terminal out of a connector. If the terminal is difficult to remove, repeat the entire procedure.

7. Repair the terminal by following the Repairing Connector Terminals procedure.

8. Insert the repaired terminal back into the cavity. Repeat the diagnostic procedure to verify the repair and reconnect the connector bodies.

Yazaki Connectors (16-Way)

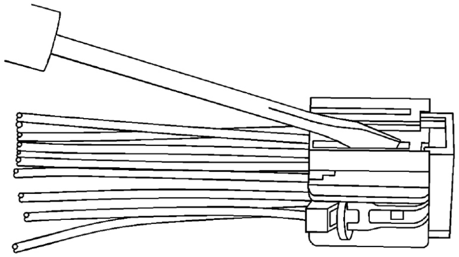
Terminal Removal Procedure



1. While depressing the lock, pull the two connector halves apart.

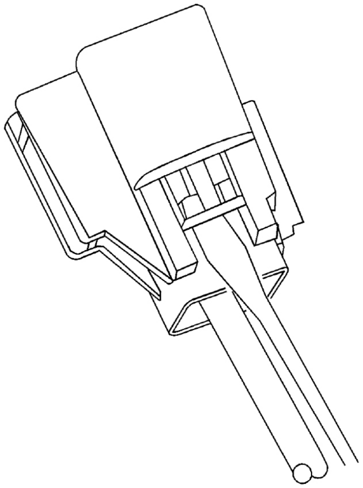
Note: The terminal position assurance (TPA) is fragile and may break if not done carefully.

2. Use a small flat-blade tool to very carefully push the TPA towards the face of the connector on both sides of the connector.



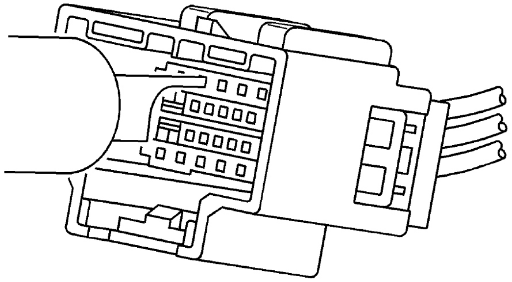
3. View of the male half of the connector with female terminals.

Yazaki Connectors (16-Way) (continued)



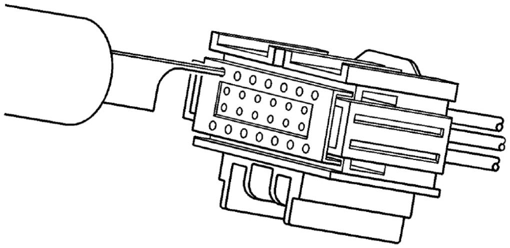
4. View of the female half of the connector with male terminals.

5. Use a terminal release tool to release the terminals by inserting the tool into the terminal release cavity.



6. View of the female half of the connector with male terminals.

Yazaki Connectors (16-Way) (continued)



7. View of the male half of the connector with female terminals.

8. While holding the removal tool in place, gently pull the wire out of the back of the connector. Always remember never use force when pulling a terminal out of a connector.

9. Repair the terminal by following the Repairing Connector Terminals procedure.

10. Insert the repaired terminal back into the cavity. Repeat the diagnostic procedure to verify the repair and reconnect the connector bodies.

Repairing Connector Terminals (Terminated Lead Repair)

Terminated leads are terminals that are crimped onto wires. The terminated lead can be used throughout the vehicle since it is designed for temperatures up to 150°C. The length of the wire is 450 mm.

1. Use the connector end view to identify the correct terminated lead.

2. The terminated lead package should include a DuraSeal splice sleeve. If not, use the chart to in Splicing Copper Wire Using Splice Sleeves in **Wire to Wire Repair** to identify the correct DuraSeal splice sleeve, refer to Splicing Copper Wire Using Splice Sleeves in Wire to Wire Repair.

Repairing Connector Terminals (Terminal Repair)

Use the following repair procedures to repair each type of terminal:

- For push to seat terminals, refer to Delphi Connectors.

- For pull to seat terminals, refer to Delphi Connectors.

Note: The first step for all terminal repairs is to find the connector end view in SI.

CABLE SEAL TERMINALS

1. Cut off the terminal between the core and the insulation crimp to minimize any wire loss.

2. Remove the old seal.

3. Apply the correct cable seal, per the wire gauge size, from the kit. Slide the seal back along the wire to enable removal of the insulation.

4. To minimize wire loss, remove only the insulation required.

5. Using the connector end view, determine the correct crimp tool and crimp jaw.

6. Align the seal with the end of the cable insulation.

7. Position the stripped wire and seal in the terminal.

8. Hand Crimp the core wings first.

9. Hand Crimp the insulation wings around the seal and the cable.

Repairing Connector Terminals (Terminated Lead Repair) (continued)

UNSEALED TERMINALS

1. Cut off the terminal between the core and the insulation crimp to minimize any wire loss.
2. To minimize wire loss, remove only the insulation required.
3. Position the stripped wire in the terminal.
4. Hand Crimp the core wings first.
5. Hand Crimp the insulation wings around the cable.

Terminal Removal

Note: All repairs near the engine manifold, turbo engine and all exhaust pipes should follow the High Temperature Wiring Repair procedures.

1. Find the appropriate connector end view within the connector end view section. The connector end view has the following information:
    - Diagnostic probe tool
    - Terminal release tool
    - Terminal/terminated lead part numbers

Note: Not using the proper test kit probe may cause damage to the terminal(s) that are probed.

2. Determine if a terminal is damaged.
    1. Locate the diagnostic probe tool from the connector end view. The connector end view describes the color and part number to help the technician find and use the correct tool.
    2. Connect the probe tool to the Digital Multimeter.
    3. Insert the probe tool into the cavity and follow the procedures from the Troubleshooting with a Digital Multimeter.
3. Disconnect the connector body to perform the repair.
4. Use the following procedure to remove the terminal from the connector body.

Note: Several procedures for specific connector bodies are called out in the Wiring Repairs section.

Terminal Removal (continued)

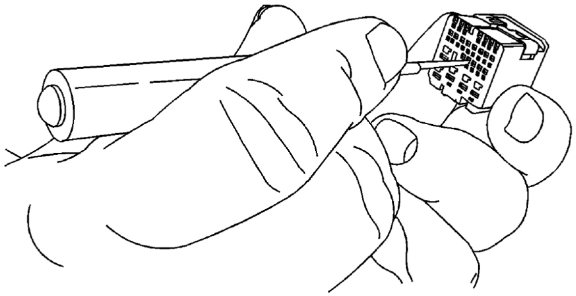
0. The terminal position assurance (TPA) and connector position assurance (CPA) should be removed before releasing the terminal for the connector body.

1. Look at the connector end view to locate the cavity of the damaged terminal and find the proper terminal release tool from the terminal release tool kit.

Note: Using the incorrect terminal release tool can damage the connector body.

Note: Some terminals have a lever that must be disengaged before the terminal can be released.

2. Insert the terminal release tool into the cavity.



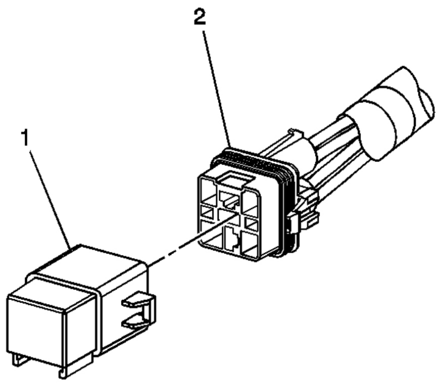
5. Gently pull the wire out of the back of the connector.

6. Repair the terminal by following the Repairing Connector Terminals procedure.

7. Insert the repaired terminal back into the cavity. Repeat the diagnostic procedure to verify the repair and reconnect the connector bodies.

Relay Replacement (Attached to Wire Harness)

Removal Procedure



1. Locate the relay.

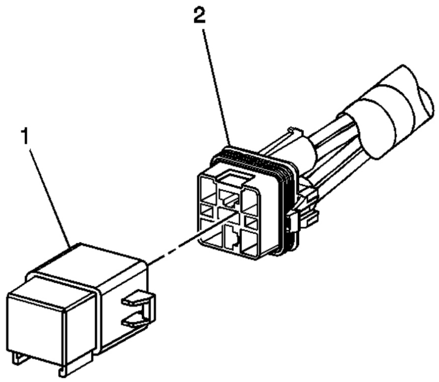
2. Remove any fasteners which hold the relay in place.

3. Remove any connector position assurance (CPA) devices or secondary locks.

Note: Use care when removing a relay in a wiring harness when the relay is secured by fasteners or tape.

4. Separate the relay (1) from the wire harness connector (2).

Installation Procedure



1. Connect the relay (1) to the wire harness connector (2).

2. Install any connector position assurance (CPA) devices or secondary locks.

3. Install the relay using any fasteners or tape that originally held the relay in place.

Relay Replacement (Within an Electrical Center)

SPECIAL TOOLS **EL-43244 Relay Puller Pliers**

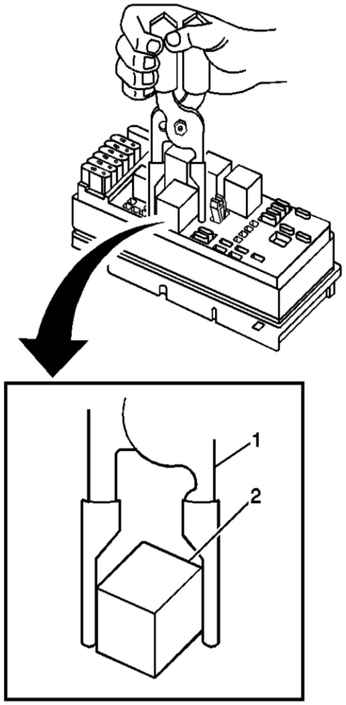
Removal Procedure

1. Remove the electrical center cover.

Note:

- Always note the orientation of the relay.
- If equipped with a notch style relay; observe the location of the notch on the old relay to verify the new relay is installed with the notch in the same location.
- Ensure that the electrical center is secure, as not to put added stress on the wires or terminals.

2. Locate the relay.



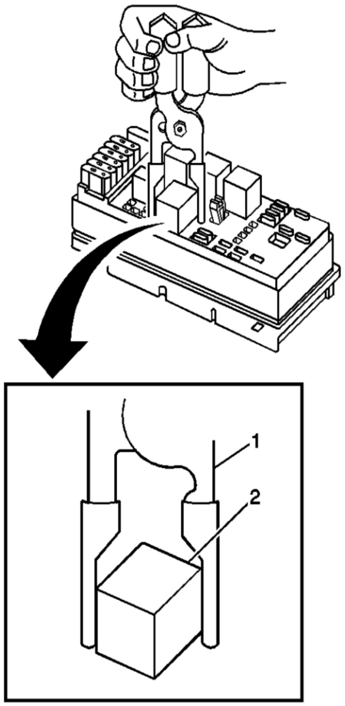
3. Using the **EL-43244** (1) position the tool on opposing corners of the relay (2).

Caution: Use **EL-43244** to pull the relay straight out from the electrical center terminals. The use of pliers or a flat bladed tool could damage the electrical center.

4. Remove the relay (2) from the electrical center.

Relay Replacement (Within an Electrical Center) (continued)

Installation Procedure



1. Install the relay (2) in the same position as removed.
2. Install the electrical center cover.

Ground Repair

ELECTRICAL GROUNDS

Proper electrical system function relies on secure, positive, corrosion-free ground connections. Loose, stripped, or corroded connections increase the possibility of improper system function and loss of module communication. These conditions may also lead to unnecessary repairs and component replacements.

In general, electrical ground connections are accomplished using one, or a combination of, three attachment methods:

- Welded M6 stud and nut
- Welded M6 nut and bolt
- Welded M8 nut and bolt

Caution: Use GM approved replacement fasteners with conductive finish for electrical ground repair.

Determine which attachment method is used, and carry out the appropriate repair.

M6 Weld Stud Replacement

1. Select a location adjacent the damaged or missing M6 ground stud having 20 mm (0.79 in) clearance behind the panel surface and 20 mm (0.79 in) clearance surrounding the M6 rivet stud flange.
2. Using GM approved residue-free solvent or equivalent, remove any grease from the repair site and allow to dry.

   Note: Ensure 20 mm (0.79 in) clearance is maintained behind the panel to be drilled.
3. Drill a 10 mm (0.40 in) diameter hole through the panel.
4. Carefully remove paint and primer from the area surrounding the rivet stud flange until bare metal is visible.

   Caution: Use GM approved replacement fasteners with conductive finish for electrical ground repair.
5. Select a replacement conductive M6 rivet stud. Reference the GM parts catalog for the correct part number and application.
6. Using a rivet stud installer, install the replacement conductive M6 rivet stud.
7. Ensure the new rivet stud is securely fastened, with no detectable movement.

   Note: The rivet stud and surrounding panel area must be properly refinished prior to the installation of the ground terminal and nut to maintain positive electrical grounding.

Ground Repair (continued)

ELECTRICAL GROUNDS (continued)

8. Completely wrap the threads of the rivet stud with painters tape or equivalent.
9. Refinish the repair area using an anti-corrosion primer.
10. Allow the refinished repair area to cure sufficiently before removing the protective material applied to the rivet stud threads.
11. Remove the painters tape or equivalent from the rivet stud threads.
12. Using GM approved residue-free solvent or equivalent, thoroughly clean the rivet stud threads to remove any adhesive and allow to dry.
13. Carefully remove any corrosion from the electrical ground wire terminal. Test for intermittent conditions and poor connections.
14. Using a small brush, apply Dielectric Lubricant GM P/N 12377900 (Canadian P/N 10953529) to the new conductive M6 rivet stud threads.
15. Install the ground terminal to the new rivet stud.
16. Select a new, conductive M6 nut. Reference the GM parts catalog for the correct part number and application.

    Caution: Fastener Caution
17. Install the conductive M6 nut and tighten to 8 Y (71 lb in).
18. Check for proper system operation.

M6 Weld Nut

Caution: Use GM approved replacement fasteners with conductive finish for electrical ground repair.

1. If the M6 weld nut at the electrical ground location is damaged or stripped, a new, conductive self-threading M7 bolt may be used to secure the ground terminal. Reference the GM parts catalog for the correct part number and application.
2. Using GM approved residue-free solvent or equivalent, remove any grease from the surface surrounding the weld nut and allow to dry.
3. Remove any loose metal particles from the damaged or stripped weld nut with a stiff brush.
4. Using a small brush, apply Dielectric Lubricant GM P/N 12377900 (Canadian P/N 10953529) to the new, conductive, self-threading M7 bolt threads.
5. Carefully remove any corrosion from the electrical ground terminal. Test for intermittent conditions and poor connections.
6. Install the electrical ground terminal to the new, conductive M7 bolt.

    Caution: Fastener Caution
7. Install the conductive M7 bolt and tighten to 9 Y (80 lb in).
8. Check for proper system operation.

Ground Repair (continued)

M6 Weld Nut (Alternative Repair)

Caution: Use GM approved replacement fasteners with conductive finish for electrical ground repair.

1. If the electrical ground location is accessible from both sides of the panel, a conductive M6 bolt and a conductive M6 nut may be used to secure the electrical ground terminal. Reference the GM parts catalog for the correct part number and application.
2. Select a location adjacent the damaged M6 weld nut having 20 mm (0.79) clearance behind the panel surface and 20 mm (0.79 in) clearance surrounding the new electrical ground site.
3. Using GM approved residue-free solvent or equivalent, remove any grease from the surface surrounding the ground location and allow to dry.

Note: Ensure 20 mm (0.79 in) clearance is maintained behind the panel to be drilled.

4. Drill a 10 mm (0.40 in) diameter hole through the panel.
5. Carefully remove paint and primer from the area surrounding the new ground site until bare metal is visible.
6. Using a small brush, apply Dielectric Lubricant GM P/N 12377900 (Canadian P/N 10953529) to the new, conductive M6 bolt threads.
7. Carefully remove any corrosion from the electrical ground terminal. Test for Intermittent Conditions and Poor Connections.
8. Install the electrical ground terminal and new, conductive M6 bolt to the ground location.
Caution: Fastener Caution

I

9. Install the conductive M6 nut and tighten to 8 Y (71 lb in).

Note: The repair area must be properly refinished to maintain positive electrical grounding.

10. Refinish the repair area using an anti-corrosion primer.
11. Check for proper system operation.

Ground Repair (continued)

M8 Weld Nut

Caution: Use GM approved replacement fasteners with conductive finish for electrical ground repair.

1. If the M8 weld nut electrical ground location is accessible from both sides of the panel, a conductive M8 bolt and a conductive M8 nut may be used to secure the ground terminal. Reference the GM parts catalog for the correct part number and application.
2. Select a location adjacent to M8 weld nut having 20 mm (0.79 in) clearance behind the panel surface and 20 mm (0.79 in) clearance surrounding the new electrical ground site.
3. Using GM approved residue-free solvent or equivalent, remove any grease from the surface surrounding the ground location and allow to dry.

Note: Ensure 20 mm (0.79 in) clearance is maintained behind the panel to be drilled.

4. Drill a 10 mm (0.40 in) diameter hole through the panel.
5. Carefully remove paint and primer from the area surrounding the new ground site until bare metal is visible.
6. Using a small brush, apply Dielectric Lubricant GM P/N 12377900 (Canadian P/N 10953529) to the new, conductive M8 bolt threads.
7. Carefully remove any corrosion from the electrical ground terminal. Test for Intermittent Conditions and Poor Connections.
8. Install the electrical ground terminal and new, conductive M8 bolt to the ground location.
Caution: Fastener Caution

9. Install the conductive M8 nut and tighten to 22 Y (16 lb ft).

Note: The repair area must be properly refinished to maintain positive electrical grounding.

10. Refinish the repair area using an anti-corrosion primer.
11. Check for proper system operation.

Ground Repair (continued)

M8 Weld Nut (Alternative Repair)

Caution: Use GM approved replacement fasteners with conductive finish for electrical ground repair.

1. If the M8 weld nut electrical ground location is not accessible from both sides of the panel, a conductive M6 rivet stud and a conductive M6 nut may be used to secure the ground terminal. Reference the GM parts catalog for the correct part number and application.
2. Select a location adjacent the damaged M8 weld nut having 20 mm (0.79 in) clearance behind the panel surface and 20 mm (0.79 in) clearance surrounding the new, conductive M6 rivet stud flange.
3. Using GM approved residue-free solvent or equivalent, remove any grease from the repair site and allow to dry.

Note: Ensure 20 mm (0.79 in) clearance is maintained behind the panel to be drilled.

4. Drill a 10 mm (0.40 in) diameter hole through the panel.
5. Carefully remove paint and primer from the area surrounding the rivet stud flange until bare metal is visible.
6. Using a rivet stud installer, install the replacement conductive M6 rivet stud.
7. Ensure the new rivet stud is securely fastened, with no detectable movement.

Note: The rivet stud and surrounding panel area must be properly refinished prior to the installation of the ground terminal and nut to maintain positive electrical grounding.

8. Completely wrap the threads of the rivet stud with painters tape or equivalent.
9. Refinish the repair area using an anti-corrosion primer.
10. Allow the refinished repair area to cure sufficiently before removing the protective material applied to the rivet stud threads.
11. Remove the painters tape or equivalent from the rivet stud threads.
12. Using GM approved residue-free solvent or equivalent, thoroughly clean the rivet stud threads to remove any adhesive and allow to dry.
13. Carefully remove any corrosion from the electrical ground wire terminal. Test for Intermittent Conditions and Poor Connections.
14. Using a small brush, apply Dielectric Lubricant GM P/N 12377900 (Canadian P/N 10953529) to the new conductive M6 rivet stud threads.
15. Install the ground terminal to the new, conductive M6 rivet stud.

Caution: Fastener Caution

16. Install the conductive M6 nut and tighten to 8 Y (71 lb in).
17. Check for proper system operation.

Ground Repair (continued)

Securing Loose Electrical Ground Connections

If the electrical ground connection is loose and the ground attachments are not damaged, properly securing the loose electrical ground may be all that is necessary. Carry out the following procedure to secure loose electrical ground connections.

Caution: Use GM approved replacement fasteners with conductive finish for electrical ground repair.

1. Using GM approved residue-free solvent or equivalent, thoroughly clean the ground stud threads and allow to dry.
2. Carefully remove any corrosion from the electrical ground wire terminal. Test for Intermittent Conditions and Poor Connections.
3. Using a small brush, apply Dielectric Lubricant GM P/N 12377900 (Canadian P/N 10953529) to the ground stud threads.
4. Install the ground wire terminal to the ground stud.

Caution: Fastener Caution

5. Install the appropriate conductive nut.
   - Conductive M6 nut: Tighten to 8 Y (71 lb in)
   - Conductive M8 nut: Tighten to 22 Y (16 lb ft)
   - Conductive M10 nut: Tighten to 45 Y (33 lb ft)
6. Check for proper system operation

Overview Notes:
Combined 'Repair Instructions' from CK and G.
Removed inappropriate [?] repairs such as battery distribution, BECs etc.

Change notes:
Rev 0 071717
Removed all large connector reference.
Removed all "special tool" references except 2
Special tool references are **bold**
All PNs listed are current in SI
All SIR reference removed

Electrical System – Customer Convenience

CUSTOMER CONVENIENCE

Customer convenience is of primary concern and importance when designing and installing electrical systems.

FUNCTION MARKING

It is recommended that the function (e.g., power sofa) and operating parameters (e.g., on/off, up/ down) of each added electrical switch be permanently printed on the switch, switch bezel or switch escutcheon plates.

LOCATION IDENTIFICATION

Upfitter owner manuals should include information on the location of all added fuses, listing the amperage rating of each fuse. If a fuse block has been added to the vehicle, it is also recommended that an illustration of the front of the fuse block be shown in the owner's manual.

INSTRUCTIONS

Upfitters should provide the customer with a "convenience packet" containing operating instructions for all added electrical accessories (i.e., TVs, VCPs, radios, cassette tape players, etc.).

DOCUMENTATION

Upfitters should provide the selling dealer and/or the buying customer with documentation or a means of obtaining documentation which, at minimum, contains the following:

- Basic schematic drawings of Upfitter-added electrical systems (see Figure 38)
- A list of cable (wire) color, gauge, function and circuit protection for all added electrical circuits (see Figure 39)
- A diagram illustrating the location of all added wiring within the vehicle (see Figure 40)
- A list of maximum additional loads (in amperes) that can be added to Upfitter circuits.

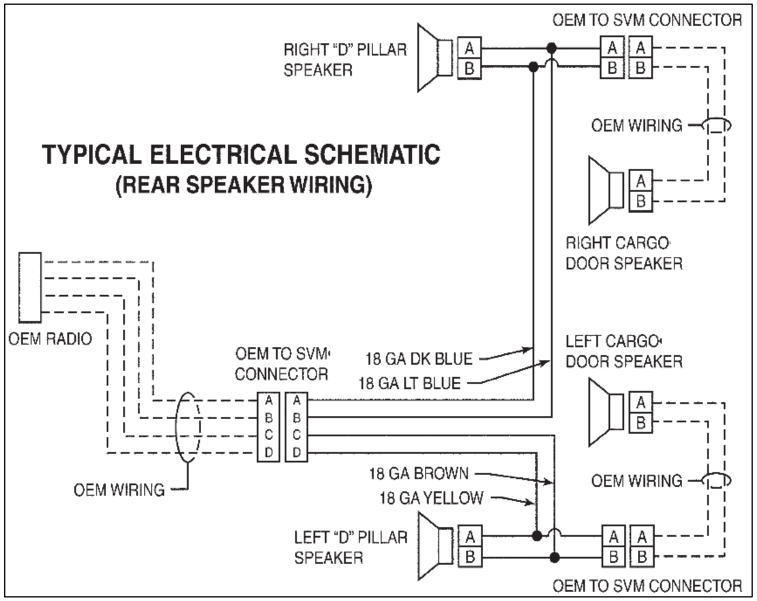
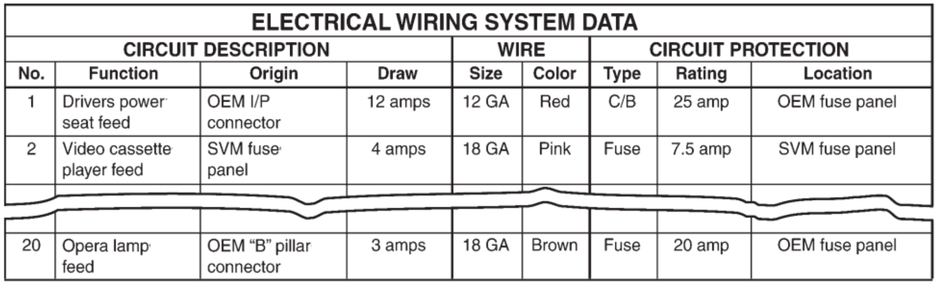

TYPICAL ELECTRICAL SCHEMATIC
(REAR SPEAKER WIRING)
OEM TO SVM CONNECTOR
RIGHT "D" PILLAR SPEAKER
OEM WIRING
RIGHT CARGO DOOR SPEAKER
OEM RADIO
OEM TO SVM CONNECTOR
18 GA DK BLUE
18 GA LT BLUE
LEFT CARGO DOOR SPEAKER
OEM WIRING
18 GA BROWN
18 GA YELLOW
OEM WIRING
LEFT "D" PILLAR SPEAKER
OEM TO SVM CONNECTOR
A
B
C
D

Figure 38

Electrical System – Customer Convenience



ELECTRICAL WIRING SYSTEM DATA								
CIRCUIT DESCRIPTION				WIRE		CIRCUIT PROTECTION		
No.	Function	Origin	Draw	Size	Color	Type	Rating	Location
1	Drivers power seat feed	OEM I/P connector	12 amps	12 GA	Red	C/B	25 amp	OEM fuse panel
2	Video cassette player feed	SVM fuse panel	4 amps	18 GA	Pink	Fuse	7.5 amp	SVM fuse panel
20	Opera lamp feed	OEM "B" pillar connector	3 amps	18 GA	Brown	Fuse	20 amp	OEM fuse panel

NOTE: The data listed in the above chart is for illustration purposes only and does not necessarily reflect actual circuit data.

Figure 39

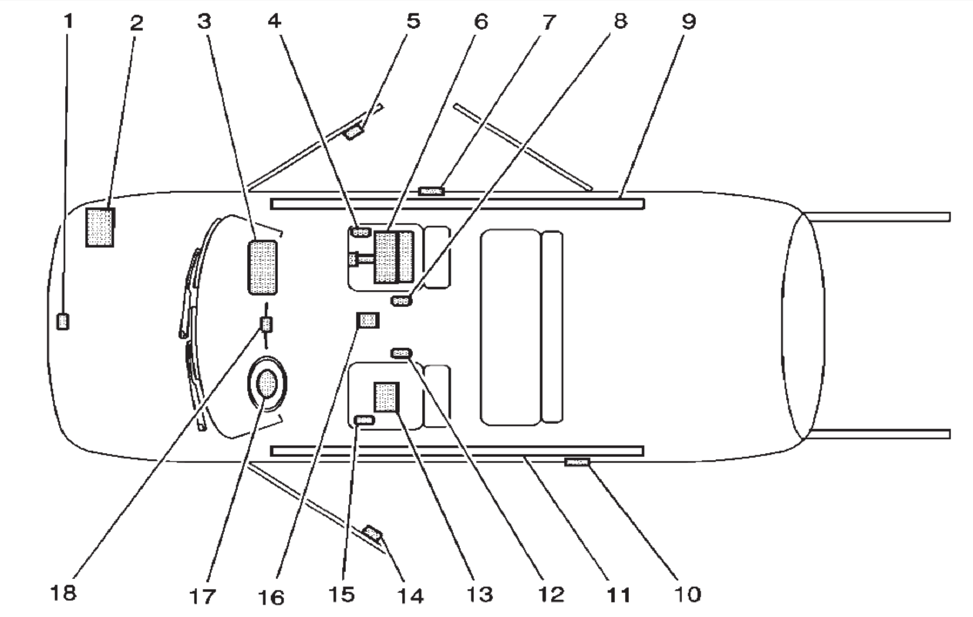


Figure 40

Electrical System – Headlamp/Fog lamp Guidelines

HEADLAMP AIMING

The Upfitter is responsible for aiming all headlamps on GM vehicles they convert prior to shipping the vehicle. Headlamps can be aimed using one of two methods:

- Mechanical aimer method
- Aiming screen method

⚠ For headlamps incorporating both high and low beams in one combination lamp, aiming is required only for the low beams.

⚠ Refer to the applicable GM Service Manual for specific headlamp aiming procedures.

Electrical System – SIR Precautions

Precautions

Caution: When performing service on or near the SIR components or the SIR wiring, the SIR system must be disabled. Refer to SIR Disabling and Enabling. Failure to observe the correct procedure could cause deployment of the SIR components, personal injury, or unnecessary SIR system repairs.

The inflatable restraint sensing and diagnostic module (SDM) maintains a reserved energy supply. The reserved energy supply provides deployment power for the air bags. Deployment power is available for as much as 1 minute after disconnecting the vehicle power. Disabling the SIR system prevents deployment of the air bags from the reserved energy supply.

SIR Disabling and Enabling

SIR component location affects how a vehicle should be serviced. There are parts of the SIR system installed in various locations around a vehicle. To find the location of the SIR components refer to SIR Identification Views. There are several reasons for disabling the SIR system, such as repairs to the SIR system or servicing a component near or attached to an SIR component. There are several ways to disable the SIR system depending on what type of service is being performed. The following information covers the proper procedures for disabling/enabling the SIR system.

Condition	Action
If vehicle was involved in an accident with an air bag deployment	Disconnect the negative battery cable(s)* Refer to Repairs and Inspections Required After a Collision in the appropriate service manual.
When performing SIR diagnostics.	Follow the appropriate SIR service manual diagnostic procedure(s)*
When removing or replacing an SIR component or a component attached to an SIR component.	Disconnect the negative battery cable(s)*
If the vehicle is suspected of having shorted electrical wires.	Disconnect the negative battery cable(s)*
When performing electrical diagnosis on components other than the SIR system.	Remove the SIR/Air bag fuse(s) when indicated by the diagnostic procedure to disable the SIR system.
* DTCs will be lost when the negative battery cable is disconnected.	

Electrical System – SIR Disabling and Enabling

SIR Identification Views

The SIR Identification Views shown below illustrate the approximate location of all SIR components available on the 2009 G/H Van. For other models, refer to the appropriate GM Service Manual.

Example Shown: 2009 Chevrolet Express / GMC Savana

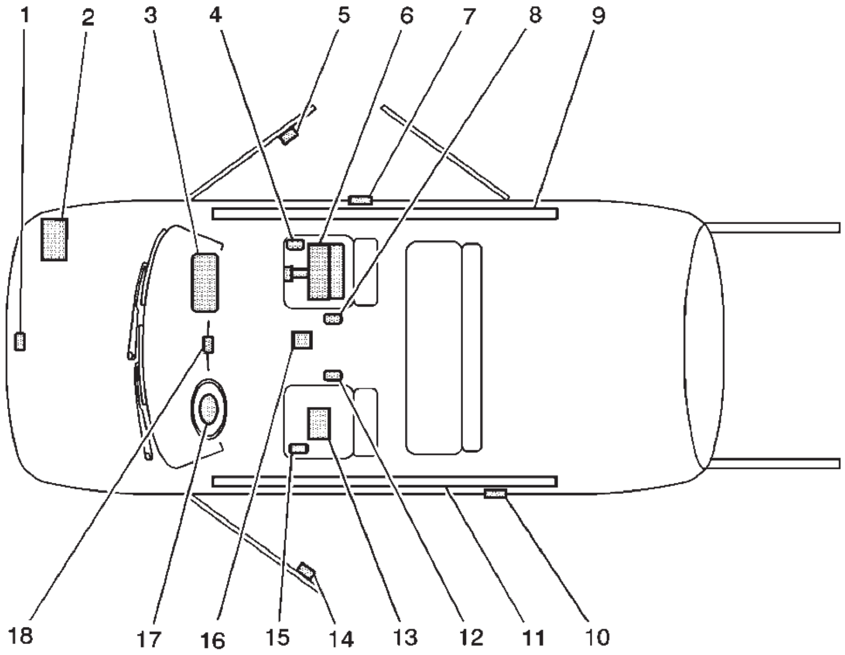


Figure 54

1	**Impact Sensor, Front** – Located under the hood on the bottom side of the radiator support, center of vehicle
2	**Vehicle Battery** – Located in the engine compartment on the passenger side I/P Air Bag – Located at the top right under the instrument panel
3	**I/P Air Bag** – Located at the top right under the instrument panel
4	**Seat Position Sensor, Passenger** – Located underneath the seat mounter to cross seat beam
5	**Side Impact Sensor (SIS), RF** – Located inside of front right door
6	**Passenger Presence System** – Located on the front passenger seat under the seat bottom trim
7	**Side Impact Sensor (SIS), RR** – Located near the side step under door step mat
8	**Seat Belt Buckle Pre-tensioner, Passenger** – Located left side of front passenger seat
9	**Inflator Module for Roof Rail Air Bag** – Either a LF located behind roof headliner for the passenger and side door or two inflator modules, a LF for the front passenger and a LR the side door
10	**Side Impact Sensor (SIS), LR** – Located LH side, inside vehicle, forward of wheel well
11	**Inflator Module for Roof Rail Air Bag, LF** – Located behind roof headliner on left side of vehicle
12	**Seat Belt Buckle Pre-tensioner, Driver** – Located right side of driver seat
13	**Sensing and Diagnostic Module (SDM)** – Located underneath the vehicle carpet under the center console
14	**Side Impact Sensor (SIS), LF** – Located inside of front left door
15	**Seat Position Sensor, Driver** – Located underneath the seat mounter to cross seat beam
16	**Rollover Sensor** – Located between front seats under carpet
17	**Steering Wheel Air Bag** – Located on the steering wheel
18	**I/P module Indicator and I/P Module Disable Switch** – Located near radio as a switch bank

Electrical System – SIR Disabling and Enabling (continued)

General Service Instructions

The following are general service instructions which must be followed in order to properly repair the vehicle and return it to its original integrity:

- Do not expose inflator modules to temperatures above 65ºC (150ºF)
- Verify the correct replacement part number. Do not substitute a component from a different vehicle.
- Use only original GM replacement parts available from your authorized GM dealer. Do not use salvaged parts for repairs to the SIR system.

Discard any of the following components if it has been dropped from a height of 91 cm (3 feet) or greater:

- Inflatable restraint sensing and diagnostic module (SDM)
- Any Inflatable restraint air bag module
- Inflatable restraint steering wheel module coil
- Any Inflatable restraint sensor
- Inflatable restraint seat belt pre-tensioners
- Inflatable restraint Passenger Presence System (PPS) module or sensor

Disabling Procedure - Air Bag Fuse

1. Turn the steering wheel so that the vehicles wheels are pointing straight ahead.

2. Place the ignition in the OFF position.

3. Locate and remove the fuse(s) supplying power to the SDM. Refer to SIR Schematics or Electrical Center Identification Views in appropriate service manual.

4. Wait 1 minute before working on the system

Important: The SDM may have more than one fused power input. To ensure there is no unwanted SIR deployment, personal injury, or unnecessary SIR system repairs, remove all fuses supplying power to the SDM. With all SDM fuses removed and the ignition switch in the ON position, the AIR BAG warning indicator illuminates. This is normal operation, and does not indicate an SIR system malfunction.

Enabling Procedure - Air Bag Fuse

1. Place the ignition in the OFF position.

2. Install the fuse(s) supplying power to the SDM. Refer to SIR Schematics or Electrical Center Identification Views in appropriate service manual.

3. Turn the ignition switch to the ON position. The AIR BAG indicator will flash then turn OFF.

4. Perform the Diagnostic System Check - Vehicle if the AIR BAG warning indicator does not operate as described. Refer to Diagnostic System Check - Vehicle in appropriate service manual.

Electrical System – SIR Disabling and Enabling (continued)

Disabling Procedure - Negative Battery Cable

1. Turn the steering wheel so that the vehicles wheels are pointing straight ahead.
2. Place the ignition in the OFF position.
3. Disconnect the negative battery cable from the battery.
4. Wait 1 minute before working on system.

Enabling Procedure - Negative Battery Cable

1. Place the ignition in the OFF position.
2. Connect the negative battery cable to the battery.
3. Turn the ignition switch to the ON position. The AIR BAG indicator will flash then turn OFF.
4. Perform the Diagnostic System Check - Vehicle if the AIR BAG warning indicator does not operate as described. Refer to Diagnostic System Check - Vehicle in appropriate service manual.

Electrical System – Welding High and Voltage Precautions

Welding Precautions

To avoid damaging the OEM electrical system or components during welding procedures, GM recommends the following precautionary measures:

- Do not route welder electrical cables on, near or across any vehicle electrical wiring or components while welding is in progress.
- Remove or adequately shield any electrical or electronic components which can be damaged by excessive temperatures created by the welding operation.
- Protect all wiring and electrical components from damage that can be caused by welding flash (sparks).
- Make sure that the welder ground clamp is of an adequate size and placed as close as possible to the area being welded. Never use a vehicle suspension component as a welding ground point.
- Prior to any welding, disconnect all battery negative cables.
- Disable the air bag system as outlined in the “SIR Service Precautions” section of this manual.
- Disconnect any electrical/electronic computer modules located near the area to be welded.

NOTE: After welding is complete, carefully inspect any electrical wiring or components in the weld area for degradation or damage.

High Voltage Precaution

Caution labels should be affixed to all electrical components, such as inverters, wiring harnesses, electro-luminescence lighting devices, etc., that either produce, transmit or operate on elevated voltages (usually 110 volts).

Electrical System – Appendix 1

Achronym or Term	Meaning	Definition
2WD	Two-Wheel Drive	Indicates that a vehicle has 2?driven wheels OR that a 4WD vehicle uses only 2?wheels for propulsion. So it can be the description of a vehicle configuration OR the operational mode of the drivetrain.
4WD	Four-Wheel Drive	Four-wheeled vehicle with a drivetrain that allows all four wheels to receive power from the engine simultaneously which provides better control on various surfaces. Can be used to describe the configuration of the vehicle OR as the operational mode of the drivetrain. 4WD vehicles usually can turn 2?wheels off to be in a 2WD mode. See also AWD.
A/C	Air Conditioning	The cooling and dehumidification of indoor air for thermal comfort.
A/D	Analog to Digital	Used in context of converting electrical analog signals to digital signals.
ABS	Antilock Braking System	System on motor vehicles which prevents the wheels from locking while braking which helps the driver maintain control in heavy braking conditions.
AC	Alternating Current	An electrical current whose magnitude and direction vary cyclically.
Accessible	Accessible, reachable	Capable of being removed or exposed without damaging the vehicle or its finished interior or exterior surfaces.
AGM	Absorbent Glass Mat	the AGM battery uses a very absorbent micro fiberglass material to trap the gas generated during discharge and recharge.
AM	Amplitude Modulation	Method of impressing data onto an alternating-current (AC) carrier waveform.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
Ampacity	Ampacity	The maximum current, expressed in amperes, that a conductor can carry on a continuous basis without exceeding the insulation's temperature rating (ampere capacity).
APP	Accelerator pedal position	Accelerator pedal position – sensor that indicates pedal position.
Approved	Acceptable to the "authority having jurisdiction."	
Automatic	Self-acting	A device that is self-acting, that operates by its own mechanism reacting to an outside stimulant such as application/loss of current, change in current strength, pressure, or mechanical configuration.
AWD	All-Wheel Drive	All-wheel-drive systems are designed to function on all types of surfaces, both on- and off-road, and most of them cannot be switched off. This can also be called full-time four wheel drive. See also 4WD.
AWG	American Wire Gauge	American wire gauge is a standardized wire gauge system used since 1857 predominantly in the United States for the diameters of round, solid, nonferrous, electrically conducting wire. E.g. a wire of AWG10 has a diameter of 2.588mm, AWG20 corresponds to a diameter of 0.812mm.
B+	Battery Positive Voltage	The electrical potential on the positive terminal of the battery.
BARO	Barometric Pressure	Atmospheric pressure as measured by a barometer.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
Battery	Electrical Storage Device	A device for storage of low-voltage electrical energy.
BCM	Body Control Module	This module supplies vehicle occupants with visual and audible information and controls various vehicle functions,
BECM	Battery Energy Control Module	Control module used to regulate the battery voltage.
BPP	Brake Pedal Position	Positon of the foot pedal that moves a piston in the master brake cylinder.
Butt splice	Connects wires together	A device used to join two wires together.
Cable	Cable or wire	See "wire."
Cable seal	Wire lead seal for a connector	A device to environmentally protect a connection system.
CAN	Controller Area Network	Serial data connection between control modules
Cavities	Wire connector feature	The areas within a connector which hold the terminals. There is one cavity for each terminal in the connector.
CCM	Chassis Control Module	The module that controls various vehicle functions on the Chassis, like Engine/Trans Mount, Active Grille Air Shutter, Load Leveling, etc…
CD	Compact Disc	A small optical disk on which data such as music, text, or graphic images is digitally encoded.
Circuit	Conductive pathway	The complete path of electric current to and from its power source.
Circuit breaker	Circuit protection device	A device designed to open a circuit automatically on a predetermined overcurrent, without damage to itself, when properly applied within its rating.
CMA	Circular Mil Area	

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
CPA	Connector Position Assurance	Part of an electrical connector that prevents the connector from moving out of its socket. Usually needs to be pressed to unlock the connector when disconnecting it.
CPP	Clutch Pedal Position	A lever operated with the foot that controls the coupling that connects or disconnects driving and driven parts of a driving mechanism.
CV	Constant Velocity	Used in conjunction with CV joints, which connect two shafts at an angle while both shafts always have the same rotational speed without variations.
CVT	Continuously Variable Transmission	A transmission in which the ratio of the rotational speeds of two shafts, as the input shaft and output shaft of a vehicle or other machine, can be varied continuously within a given range, providing an infinite number of possible ratios which improves fuel economy.
D	Drive	D on the transmission gear selector lever.
DAB	Digital Audio Broadcast	Technology for broadcasting of audio using digital radio (carries information via digital signal) transmission.
DC	Direct Current	Continuous current, constant flow of electric charge.
DLC	Data Link Connector	This is an electronic connector typically located underneath the driver's side dashboard, just above the pedals. The connector has 16?pins.
DMM	Digital Multimeter	Electronic measuring instrument that combines several functions in one unit. The most basic instruments include an ammeter, voltmeter, and ohmmeter.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
DOHC	Dual Overhead Camshaft	Dual overhead camshafts (DOHC) are higher performance engines, they produce more power, and can run at higher speeds because they allow an engine to have four valves per cylinder. Each camshaft operates two of the valves, one camshaft handles the intake valves, and one handles the exhaust valves.
DPF	Diesel Particulate Filter	Device designed to remove diesel particulate matter or soot from the exhaust gas of a diesel engine.
DRL	Daytime Running Lamps	White lights mounted on the front of an automobile that automatically switch on when the key is turned and are intended for daytime use, to increase the visibility of the automobile.
DSCC	Distance Sensing Cruise Control	A type of cruise control that automatically maintains the distance between vehicles.
DSP	Digital Signal Processor	A specialized microprocessor designed specifically for digital signal processing, generally in real-time computing.
DTC	Diagnostic Trouble Code	An electronic signal stored in an automotive computer, indicating the presence of a fault detected by that computer.
DVD	Digital Video Disk	A popular optical disc storage media format the size of a CD. Used mainly for movies but also for data
DVOM	Digital Volt Ohm Meter	Electronic measuring instrument that displays measurements in numeric format as opposed to an indicator needle. The most basic instruments include a voltmeter and ohmmeter.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
EBCM	Electronic Brake Control Module	This module contains a microprocessor and software for antilock braking system operation.
ECM	Engine Control Module	This electronic module works with a vehicle's sensors and engine control devices to insure that the engine operates at maximum efficiency and performance. It performs three vital functions. Receives electronic signals from engine sensors. Analyzes the data and makes an engine performance decision (based on the pre-set parameters within the unit). Sends an "output command" to an actuator that adjusts engine performance.
ECT	Engine Coolant Temperature	A measure of how hot or cold the fluid which flows through the engine in order to prevent its overheating, transferring the heat produced by the device to other devices that utilize or dissipate it.
EEPROM	Electrically Erasable Programmable Read-Only Memory	A non-volatile storage chip used in computers and other devices to store small amounts of volatile data, e.g. calibration tables or device configuration.
EGR	Exhaust Gas Recirculation	Is an NOx (nitrogen oxide and nitrogen dioxide) reduction technique used in most gasoline and diesel engines. EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinders.
EMI	Electromagnetic Interference	Electromagnetic interference (also called radio frequency interference) is a disturbance that affects an electrical circuit due to either electromagnetic conduction or electromagnetic radiation emitted from an external source.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
Equipment	Device or assembly	Any material, device, appliance, fixture, etc., used as part of, or in connection with, the electrical system.
Exposed	Uncovered	Unprotected from inadvertent contact by another component, part or item.
ESD	Electrostatic Discharge	The sudden and momentary electric current that flows between two objects at different electrical potentials.
EV	Electric Vehicle	A category of vehicles that only have an electric drive system.
EVAP	Evaporative Emission	A system that controls the fuel fumes in the fuel tank.
FM	Frequency Modulation	In telecommunication this is a way to convey information over a carrier wave by varying its frequency.
Fuse	Circuit protection device	A specifically rated overcurrent protective device that incorporates a circuit-opening fusible part that is severed by the heat generated by the overcurrent passing through it.
Fuse holder	Fuse holder	A device in which a single fuse is securely held, providing isolation of the source conductor from the distributing conductor.
FWD	Front-Wheel Drive	A form of engine/transmission layout used in motor vehicles, where the engine drives the front wheels only.
GMLAN	General Motors Local Area Network	A local-area network is a computer network covering a small geographic area, like a home or vehicle. This specific type of LAN connects several controllers inside the vehicle and was developed by General Motors.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
GPS	Global Positioning System	Satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense.
GPT	General Purpose Thermoplastic	General purpose thermoplastic; PVC insulated wire.
GSM	Global System for Mobile Communications	Globally accepted standard for digital cellular communication.
GVW	Gross Vehicle Weight	Maximum total weight of a road vehicle or trailer that is loaded, including the weight of the vehicle itself plus fuel, passengers, cargo, and trailer tongue weight.
HD	Heavy Duty	Robust design to accommodate large work loads.
HID	High Intensity Discharge	A type of light that produces a bright light by using gas filled bulbs. (gas is usually mercury, metal halide, and high-pressure sodium) Uses very little battery power and is a very "cool" light.
HO2S	Heated Oxygen Sensor	Heated oxygen sensors have an internal heater circuit that brings the sensor up to operating temperature more quickly than an unheated sensor. An oxygen sensor must be hot (about 600–650°F) before it will generate a voltage signal. The hot exhaust from the engine will provide enough heat to bring an O2 sensor up to operating temperature.
HVAC	Heating Ventilation Air Conditioning	This system is sometimes referred to as climate control. Ventilation air ducts installed throughout a vehicle that supply conditioned air to a room through rectangular or round outlet vents.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
I^2C	Inter-Integrated Circuit	Serial data connection between Integrated Circuits (microchips) inside a control module invented by Phillips
IAT	Intake Air Temperature	Temperature of the air entering intake air flow system of the engine.
ICE	Internal Combustion Engine	An engine in which the combustion of fuel and an oxidizer (typically air) occurs in a confined space called a combustion chamber.
ID	Identification	Number or Code that identifies a component or control module. Can be written on the part or be transmitted on a bus or via radio.
Incomplete vehicle	Vehicle that must be finished by an upfitter	An assemblage consisting, as a minimum, of frame and chassis structure, powertrain, steering system, suspension system, and braking system, to the extent that those systems are to be part of the completed vehicle.
Indexing feature	Error proofing feature	Mechanical feature of a connector (usually a tab and slot) which allows connectors to be mated in only one way.
Inductive load	Usually a coil	Any device (motors, magnetic solenoid, etc.) that utilizes a process by which electrical energy is used to create magnetic fields and forces.
Inertia lock		The locking device on a connector that keeps connectors together once mated.
Isolated circuitry		A wiring system with distribution and overcurrent protection totally separate and independent from the vehicle's OEM wiring system.
ISP	Internet Service Provider	A company that furnishes corporations and individual consumers with various services, mainly access to the Internet.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
ISP	Internet Service Provider	A company that furnishes corporations and individual consumers with various services, mainly access to the Internet.
ISS	Input Shaft Speed	Rotational speed of the input shaft of a transmission.
LAN	Local Area Network	Standard network connection PC's.
LCD	Liquid Crystal Display	A thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector.
LED	Light Emitting Diode	Small light bulbs that fit easily into an electrical circuit they do not have a filament that will burn out, and they do not get especially hot. They are illuminated solely by the movement of electrons in a semiconductor material.
LIN	Local Interconnect Network	Computer networking bus system used within automotive network architectures. Similar to CAN, but cheaper and less powerful.
Low voltage	Not generally harmful to humans	An electromotive force rated 24 volts, nominal or less, generally 12 volts in automotive applications.
OEM	Original Equipment Manufacturer	Vehicle manufacturer
LPG	Liquefied Petroleum Gas	A mixture of mainly propane and butane, produced commercially and stored under pressure to keep it in a liquid state.
MAF	Mass Air Flow	The amount of air drawn into the engine
MAP	Manifold Absolute Pressure	Pressure in the engine intake system after the throttle valve referenced to a perfect vacuum.
MDI	Multiple Diagnostics Interface	A device used by GM dealers that enables a PC to communicate with the control modules in a vehicle.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
MDI	Multiple Diagnostics Interface	A device used by GM dealers that enables a PC to communicate with the control modules in a vehicle.
MIL	Malfunction Indicator Lamp	An indicator of the internal status of a car engine.
MOST	Media Oriented Systems Transport	Serial communication bus to transmit audio and video information.
N	Neutral	A state of the transmission in which it is not engaged.
NiMH	Nickel Metal Hydride	A type of rechargeable battery that uses a hydrogen absorbing alloy for the negative electrode.
NOx	Nitrogen Oxides	Refers to any of the following oxygen compounds of nitrogen or a mixture of them. Nitric Oxide, Nitrogen dioxide, Nitrous Oxide, Dinitrogen trioxide, Dinitrogen tetroxide, Dinitrogen pentoxide.
O2	Oxygen	A colorless, odorless, tasteless, gaseous chemical element with the chemical symbol?O and atomic number?8.
O2S	Oxygen Sensor	An electronic device that measures the proportion of oxygen (O2) in the gas or liquid being analyzed.
OBD	On-Board Diagnostic	A generic term referring to a vehicle's self-diagnostic and reporting capability.
OEM	Original Equipment Manufacturer	A producer that provides a product to its customers, who proceed to modify or bundle it before distributing it to their customers.
Open circuit	No conduction path	Condition by which electrical continuity is disrupted or broken in an electrical circuit.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
OSS	Output Shaft Speed	Rotational speed of the output shaft of a transmission.
Overcurrent		Any current that exceeds the rated current of equipment or ampacity of a conductor. Overcurrent may result from overload, short circuit or ground fault. Overcurrent protection device
P	Park - a state in which the transmission is set so one can leave the vehicle.	
P	Park	A state in which the transmission is set so one can leave the vehicle.
PCB	Printed Circuit Board	A thin plate on which chips and other electronic components are placed.
PCM	Powertrain Control Module	A control module that features the functions of both, the engine and the transmission control module.
PCMCIA	Personal Computer Memory Card Industry Association	An international standards body and trade association with over 100?member companies that was founded in 1989 to establish standards for Integrated Circuit cards and to promote interchangeability among mobile computers where ruggedness, low power, and small size were critical.
Pigtail	Device with wires	External conductors (wire leads) that originate within an electrical component or device.
PIN	Personal Identification Number	A secret numeric password shared between a user and a system that can be used to authenticate the user to the system.
Power source	Power Connection Point	The specific location or point that electrical current is obtained to supply the conversion wiring system.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
Power source	Power Connection Point	The specific location or point that electrical current is obtained to supply the conversion wiring system.
PPE	Personal Protective Equipment	Protective clothing, helmets, goggles, or other garment designed to protect the wearer's body from injury.
PRNDL	Park, Reverse, Neutral, Drive, Low	Park, Reverse, Neutral, Drive, Low (automatic transmission positions).
PTC	Positive Temperature Coefficient	Refers to materials that experience an increase in electrical resistance when their temperature is raised.
PTO	Power Take-Off	A transmission gear or external splined driveshaft, usually on a tractor or truck that can be used to provide power to an attachment or separate machine. This mechanism allows implements to draw energy from the engine.
PTOM	Power Take Off Module	
PVC	Polyvinyl Chloride	A thermoplastic copolymer.
PWM	Pulse Width Modulation	Square shaped type of signal that carries the information in the ratio between on and off times.
R	Reverse	Rearward: directed or moving toward the rear;
RAM	Random Access Memory	A type of computer data storage. It today takes the form of integrated circuits that allow the stored data to be accessed in any order.
Rating maximum	Circuit interruption point	The point of highest current that a circuit breaker or fuse is intended to interrupt at under specified test conditions.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
RCT	Radiator Coolant Temperature	This is the heat intensity of the radiator coolant measured in degrees. The radiator is a part of the cooling system that removes the engine heat. Coolant is a mixture of water and antifreeze (ethylene glycol) which lowers the freezing point of the water in the coolant system, this fluid also picks up heat from the engine and transfers it to the air.
RDS	Radio Data System	A standard from the European Broadcasting Union for sending small amounts of digital information using conventional FM radio broadcasts.
RF	Radio Frequency	A frequency or rate of oscillation within the range of about 3?Hz and 300?GHz. This range corresponds to frequency of alternating current electrical signals used to produce and detect radio waves.
Ring terminal	Round wiring terminal	Part used to connect wiring leads to threaded studs or directly to sheet metal. Also see “Terminal.”
ROM	Read-Only Memory	A class of storage media used in computers and other electronic devices. Data stored in ROM cannot be modified.
RPO	Regular Production Option	A three digit/letter code given to parts, assemblies, and systems originally installed on the vehicle. These RPO codes designate options and are assigned by General Motors.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
RSA	Rear Seat Audio	An auxiliary set of controls that operate the main audio system from the rear seat. Rear passengers can also operate a different media source than the front passengers.
RVIA	Recreation Vehicle Industry Association SAE	Society of Automotive Engineers
RWD	Rear-Wheel Drive	A common engine/transmission layout in which the engine is in the front of the vehicle, but the front mid-engine, rear mid-engine and rear engine layouts are also used.
SCV	Speed Controlled Volume	The volume control is set for a desired sound level in the vehicle as the vehicle increases its speed, the sound level is adjusted.
SDM	Sensing and Diagnostic Module	The name given to air bag modules used in General Motors vehicles.
Sealed	Environmentally protected	Closed or secured tightly for protection from environmental factors such as moisture or noxious fumes.
Secondary lock or TPA lock		Terminal position assurance lock; a separate or hinged part of a connector which prevents terminals from pulling out of the back of the connector.
SIM	Subscriber Identity Module	Part of a removable smart card Integrated Circuit Card. This is used for mobile cellular telephone devices such as mobile computers and mobile phones. SIM cards securely store the service-subscriber key used to identify a subscriber. The SIM card allows users to change phones by simply removing the SIM card from one mobile phone and inserting it into another mobile phone or broadband telephony device.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
SIR	Supplemental Inflatable Restraint	Technical term for the air bag. Air bag is a stretchable membrane, which inflates during an automobile accident to provide cushioning to the passenger's head and torso to prevent injury to the passengers.
SPI	Serial Peripheral Interface	This is an interface that enables the serial (one bit at a time) exchange of data between two devices. An SPI operates in full duplex mode. This means that data can be transferred in both directions at the same time. It is a standard bus technology like CAN or I2C.
Splice clip	Connection device	A device used to facilitate splicing three or more wires.
SPS	Service Programming System	System that enables repair facilities to update the software in control modules.
SUV	Sport Utility Vehicle	A passenger vehicle which combines the towing capacity of a pickup truck with the passenger-carrying space of a minivan.
SVS	Service Vehicle Soon	Indicator lamp or symbol for a malfunction related to a vehicle component or system.
TA	Traffic Announcement	Message spoken on radio regarding the movement of vehicles or pedestrians through an area or along a route. The buttons on radios that enable this announcements are also often labeled TA.
TAC	Throttle Actuator Control	A motor which moves the engine throttle plate or valve, controlled by the engine control module. A throttle plate limits the amount of air entering a internal combustion gasoline engine.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
TAP	Transmission Adaptive Pressure	The transmission control module learns each component's characteristics and adjusts fluid pressure accordingly.
TCC	Torque Converter Clutch	Resides in a torque converter to connect an engine to an automatic transmission. The clutch is applied when conditions are correct to achieve a 1:1?ratio of engine crankshaft to transmission input shaft.
TCM	Transmission Control Module	A module that controls electronic automatic transmissions. It uses sensors from the vehicle as well as data provided by the Engine Control Module to calculate how and when to change gears in the vehicle for optimum performance, fuel economy and shift quality.
TDC	Top Dead Center	The piston is in its highest position relative to the combustion chamber.
Terminal	Wire connection device	A metal device at the end of a wire or device which provides the electrical connection. Terminals are referred to as either male or female. TPA lock
TIS	Techline Information System	The PC-based global dealership diagnostic software that provides the technician the ability to reference the most recent service information via the service department's computer.
TPA	Terminal Position Assurance	An additional locking mechanism inside an electric connector that holds the pins in place.
TV	Television	A telecommunication system for broadcasting and receiving moving pictures and sound over a distance.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
TV	Television	A telecommunication system for broadcasting and receiving moving pictures and sound over a distance.
USB	Universal Serial Bus	A type of communication bus connection between a computer and a peripheral device.
VCI	Vehicle Communications Interface	A diagnostic tool that communicates to modules of multiple communication protocols in a vehicle by converting vehicle serial data into PC serial data communication.
VCI Number	Vehicle Change Index Number	Used by GM Service support to update the vehicle software list when software [calibration file] changes are to be loaded to a vehicle i.e. modifications to the 'as built' listing
VIN	Vehicle Identification Number	Used by manufacturers to uniquely identify motor vehicles using 17?characters.
Volt	Electrical unit of measure	A unit of electromotive force equal to a force that, when steadily applied to a conductor with a resistance of 1 ohm, produces a current of 1 ampere.
VSCM	Vehicle Stability Control Module	This module uses information from several sensors to detect a loss of vehicle traction, then works with the antilock brake system to apply individual brakes to help keep the vehicle on its intended path.
VSS	Vehicle Speed Sensor	Sends data regarding how fast the car is traveling at the moment of driving. It is designed to be able to record the rate at which the vehicle's crankshaft is spinning.
WLAN	Wireless Local Area Network	Standard to transmit digital data via radio frequency.

Electrical System – Appendix 1 (continued)

Achronym or Term	Meaning	Definition
WOT	Wide Open Throttle	When the throttle blade or valve is at its maximum open position, allowing maximum air to enter an internal combustion gasoline engine.
XM	XM (Satellite Radio)	XM Satellite Radio Holdings (XM) is one of two satellite radio services in the United States and Canada. XM provides pay-for-service radio, analogous to cable television. Its service includes 73?different music channels, 39?news, sports, talk, and entertainment channels, 21?regional traffic and weather channels and 23?play-by-play sports channels (2008).
XML	Extensible Markup Language	A markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable.

Electrical System – Appendix 1 (continued)

UNITS

Unit	Meaning	Definition
m^2	Square Meter	Area
A	Ampere	Electrical
Ah	Ampere Hour	Electrical
C	Coulomb	Electrical
dBm	Decibel Meter	Electrical
dBmV	Decibel Millivolt	Electrical
mV/DIV	Millivolts per Division	Electrical
mV/s	Millivolts per Second	Electrical
Ω	Ohm	Electrical
V	Volt	Electrical
V/DIV	Volts per Division	Electrical
V/ms	Volts per Millisecond	Electrical
W	Watt	Electrical
mm^3/stroke	Cubic Millimeters per Stroke	Flow
gal/h	Gallons per Hour	Flow
g/s	grams per second	Flow
g/stroke	Grams per Stroke	Flow
kg	Kilogram	Weight
kg/100km	Kilograms per 100 Kilometer	Flow
kg/h	Kilograms per Hour	Flow
km/L	kilometer/liter	Flow
L/100km	Liters per 100 Kilometers	Flow
L/h	Liters per Hour	Flow
L/min	Liters per Minute	Flow
MPG	Miles per Gallon	Flow
mg/s	Milligrams per Second	Flow
mg/stroke	Milligrams per stroke	Flow
ft	feet	Length
in	Inch	Length
m	Meter	Length
mi	Mile	Length
bar	Bar	Mechanical
bar/min	Bars per Minute	Mechanical
in. H2O	Inches of Water	Mechanical
in. H2O/s	Inches of Water per second	Mechanical
kPa/s	Kilopascals per Second	Mechanical
N	Newton	Mechanical
Y	Newton Meter	Mechanical
Pa	Pascal	Mechanical
Pa/s	Pascals per Second	Mechanical
lb ft	Pound Foot	Mechanical
PSI	Pound-Force per Square Inch	Mechanical
Counts	Counts	Misc.
Cycles	Cycles	Misc.
dB	Decibel	Misc.
°	Degree	Misc.
°C	Degree Centigrade	Misc.
°CA	Degree Crankshaft Angle	Misc.
°F	Degree Fahrenheit	Misc.
°/s	Degree per Second	Misc.
Hz	Hertz	Misc.
kbit/s	Kilobit per second	Misc.
lx	Lux	Misc.
ppm	Parts per Million	Misc.
%	Percent	Misc.
%/min	Percents per Minute	Misc.
%/sec	Percents per Second	Misc.
Pulses	Pulses	Misc.
:1	Ratio	Misc.
RPM	Revolutions per Minute	Misc.
Steps	Steps	Misc.
W/m^2	Watts per Square Meter	Misc.
g	g (Acceleration)	Movement
km/h	Kilometers per Hour	Movement
m/s	Meters per Second	Movement
m/s^3	Meters per Second Cubed	Movement
m/s^2	Meters per Second Squared	Movement
MPH	Miles per Hour	Movement
mm/s	Millimeters per Second	Movement
d	Day	Time
h	Hour	Time
hh:mm:ss	Hour:Minute:Second	Time
ms/DIV	Milliseconds per Division	Time
min	Minute	Time
s	Second	Time
s/DIV	Seconds per Division	Time
yy-mm-dd	Year-Month-Day (2 digits)	Time
yyyy-mm-dd	Year-Month-Day (4 digits, preferred)	Time
m^3	Cubic Meter	Volume
gal	Gallon	Volume
L	Liter	Volume
mL	milliliters	Volume
US gal	US Gallon	Volume
US pt	US Pint	Volume
US qt	US Quart	Volume
kg	Kilogram	Weight

Electrical System – Appendix II – Connecting Terminology

CONNECTING TERMINOLOGY

Connection system:

A group of parts the purpose of which is to make an electrical connection between wires or wiring harness assemblies and is mechanically detachable.

Wire:

An electronically conductive core material (usually copper) covered with a non-conductive insulation. Also referred to as “lead” or “cable.”

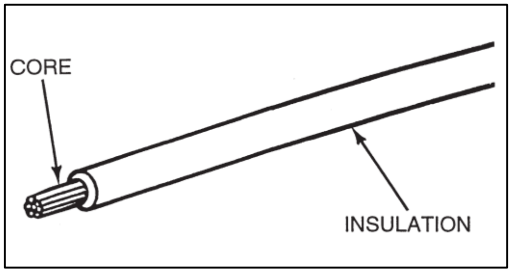


Figure 54

Connector:

A plastic molded part which houses one or more terminals and provides the mechanical connection in the connection system.

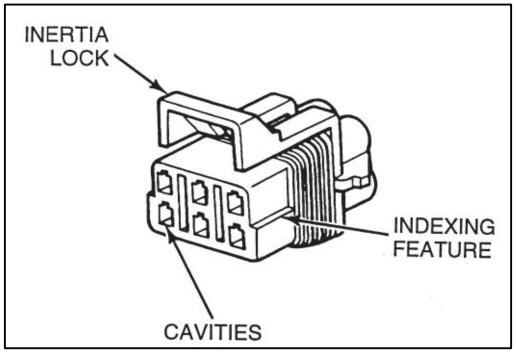


Figure 55

Indexing feature:

A mechanical feature of a connector (usually a tab and slot) which allows connectors to be mated in only one way.

Electrical System – Appendix II – Connecting Terminology

Inertia lock:

A locking device on a connector that keeps connectors together once mated.

Cavities:

Areas within a connector which hold the terminals. There is one cavity for each terminal in the connector.

Terminal:

Metal part attached (crimped) to the end of a wire which provides the electrical connection. Terminals are referred to as either “male” or “female.”

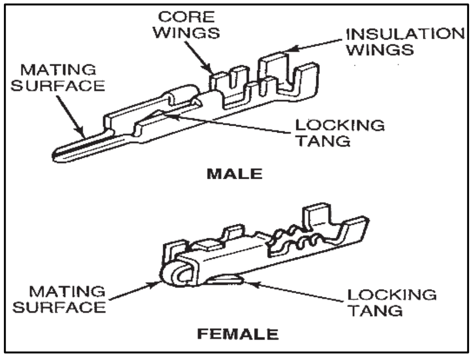


Figure 56

Core wings:

A part of the terminal which is crimped to the wire core to make an electrical connection between the wire and the terminal.

Insulation wings:

A part of the terminal which is crimped to the wire insulation to provide added retention strength, strain relief for the core crimp, and in a sealed system, to hold the cable seal.

Locking tang:

A metal tab on a terminal that locks the terminal in the connector cavity.

Secondary lock or TPA lock:

Terminal position assurance lock; a separate or hinged part of a connector which helps keep terminals from pulling out of the back of the connector.

Electrical System – Appendix II – Connecting Terminology

CPA lock:

Connector position assurance lock; a plastic tab that can be inserted through a hole in the inertia lock which provides a redundant lock between connectors and ensures proper mating.

Cable seal:

Three-ribbed seal that is attached to a wire and provides environmental protection in a connection system.

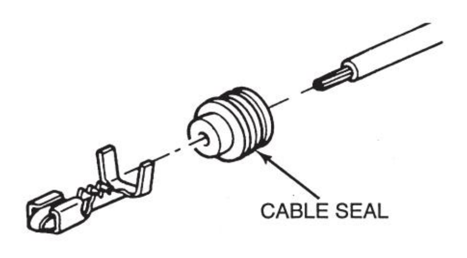


Figure 57

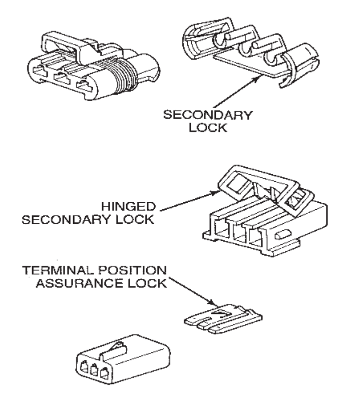

SECONDARY LOCK
HINGED SECONDARY LOCK
TERMINAL POSITION ASSURANCE LOCK

Figure 58

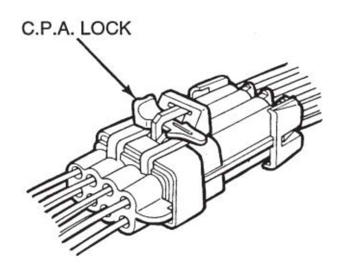


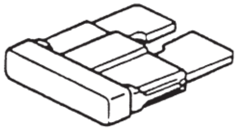
Figure 59

Electrical System – Appendix II – Fuses

ATO FUSE

Characteristics:

- Common automotive fuse, widely available for use in both a sealed or unsealed connection system

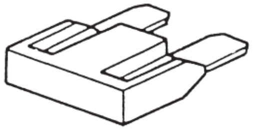
AMPERE RATING	FUSE COLOR	GM PART NUMBER	LITTLEFUSE PART NUMBER	ATO FUSE GRAPHIC
3	VIOLET	12004003	0257003.PXOCR	
5	TAN	12004005	0257005.PXOCR	
7.5	BROWN	12004006	0257007.PXOCR	
10	RED	12004007	0257010.PXOCR	
15	LIGHT BLUE	12004008	0257015.PXOCR	
20	YELLOW	12004009	0257020.PXOCR	
25	NATURAL	12004010	0257025.PXOCR	
30	LIGHT GREEN	12004011	0257030.PXOCR	

MAXI FUSE

Characteristics:

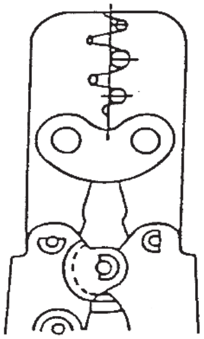
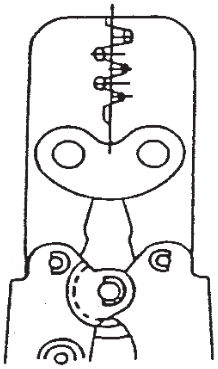
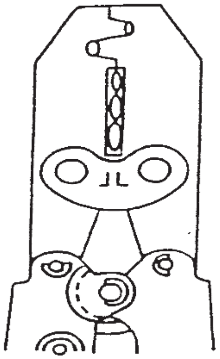
- Designed to replace fusible links – slower blow time than ATO Fuses

- Higher current fuses

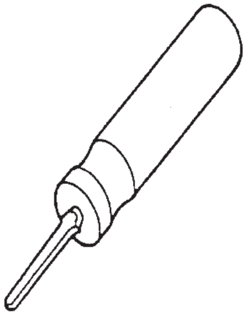
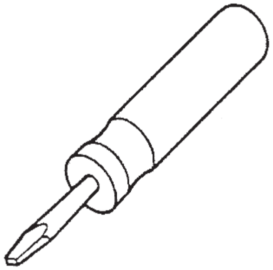
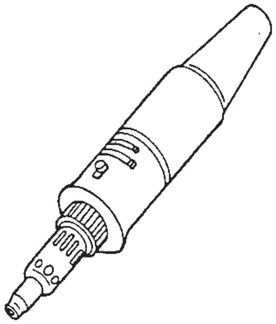
AMPERE RATING	FUSE COLOR	GM PART NUMBER	LITTLEFUSE PART NUMBER	MAXI FUSE GRAPHIC
20	YELLOW	12065931	0299020.PXOCR	
30	GREEN	12065932	0299030.PXOCR	
40	AMBER	12065933	0299040.PXOCR	
50	RED	12065934	0299050.PXOCR	
60	BLUE	12065935	0299060.PXOCR	

Electrical System – Appendix II – Available Tools

Crimping Tools

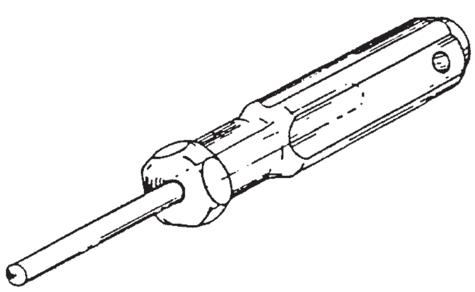
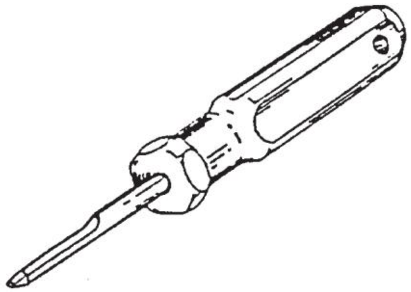
 **Terminal Crimping Tool**	 **Terminal Crimping Tool**	 **Terminal Crimping Tool**

OTHER TOOLS

 **Standard Small Pick - Green**	 **Standard Large Pick - Blue**	 **Ultra torch for heat-shrinking tubing and soldering**

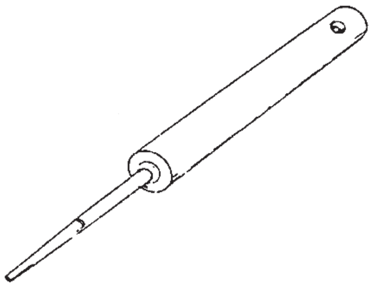
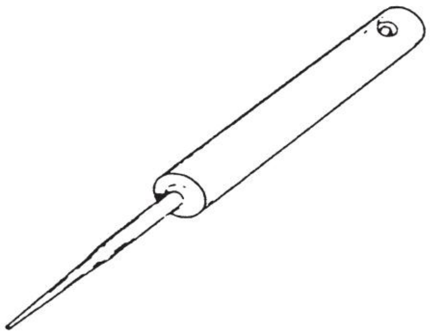
Electrical System – Appendix II – Available Tools (continued)

TERMINAL REMOVAL TOOL

	
This tool is designed to remove Weather Pack and Com-Pack I Terminals from connectors.	***This tool is designed to remove Micro-Pack Terminals from connectors.***

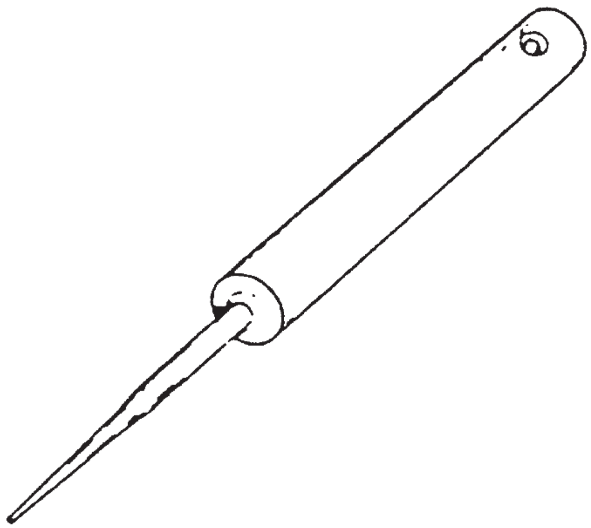
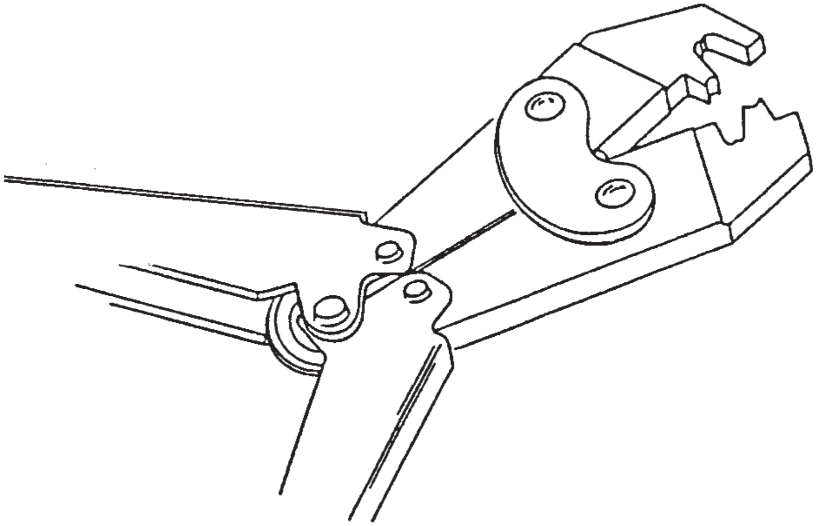
STANDARD TERMINAL REMOVAL TOOL

These tools are designed to remove terminals from various connectors. Use the appropriate size pick to avoid damage to the terminal being removed.

 **Wide Pick**	 **Narrow Pick**
Use with 56 Series male and female terminals.	***Use with Pack-Con female, Pin Grip, Edge Board, Metri-Pack male and female Pull-to-Seat and Com-Pack III Terminals***

Electrical System – Appendix II – Available Tools (continued)

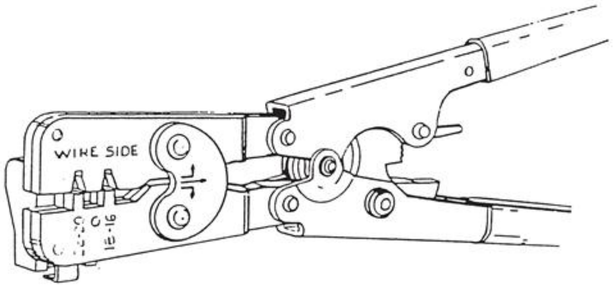
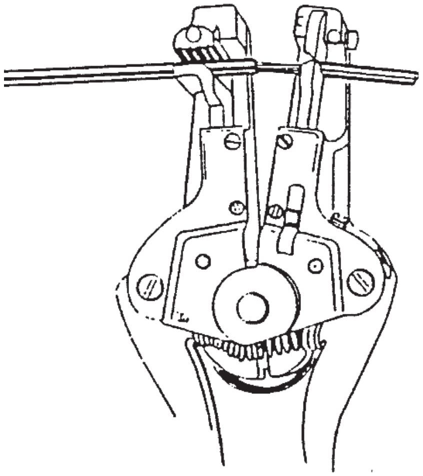
Miscellaneous Tools

TERMINAL REMOVAL TOOL	STANDARD CRIMPING TOOL
	

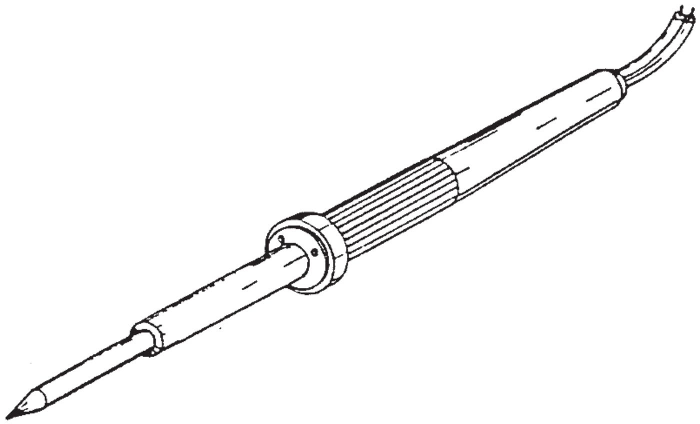
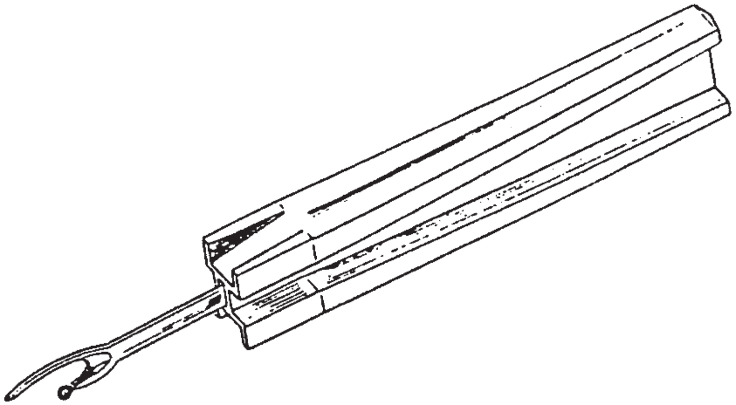
This tool is designed to remove Com-Pack II. Molex and AMP terminals from connectors.

This tool is designed for crimping male and female terminals to 10 through 18-gauge wire and similar splice clips.

Electrical System – Appendix II – Available Tools (continued)

CRIMPING TOOL	WIRE STRIPPERS
	
This tool is designed for crimping male and female Weather Pack terminals (and seals) to 14 through 20 gauge wires.	***This tool is designed for stripping cable insulation on 8 through 22-gauge wires.***

Electrical System – Appendix II – Available Tools (continued)

SOLDERING IRON	**TAPE RIPPER - STANDARD**
	
This tool is designed for apply heat for the soldering of terminal and splice clip applications.	***This tool enables quick removal of tape with no damage to wire.***

Index

PAINT AND SEALING **1**
- Sealants 1
- Bonding Principles 1
- Reactive and Non-Reactive Sealants 1
- Solvent Type Sealants 2
- GM Specifications 2
- Surface Preparation 2
- Paint 2
- Standards 2

SURFACE APPEARANCE **4**
- Paint Audit Procedure 4
- Quality Requirements For Appearance Attributes 4
- Distinctiveness Of Image (DOI) 4
  - Table 1 – Appearance Zones 4
  - Table 2 – Distinctiveness of Image (DOI) 5
- Gloss 5
  - Table 3 – Gloss 5
- Orange Peel 5
  - Table 4 – Orange Peel 5
- Uniformity 5
- Mottle 6
  - Table 5 – Mottle 6

PAINT SURFACE BLEMISHES **7**
- Paint Chips 7
- Craters 7

Index (cont'd)

Paint Surface Blemishes (continued)

- Dirt.......7
  - Table 6 – Paint Chips.......7
  - Table 7 – Craters.......7
  - Table 8 – Dirt (In Paint).......7
- Dings.......8
- Overspray.......8
- Pinholes/Popping.......8
- Polish Marks.......8
  - Table 9 – Dings.......8
  - Table 10 – Overspray.......8
  - Table 11 – Pinholes/Popping.......8
- Sags and Runs.......9
  - Table 12 – Sags and Runs.......9

PAINTED BODY APPEARANCE.......10

- Sand Scratches.......10
- Scratches.......10
- Water Spots.......10
  - Table 13 – Sand Scratches.......10
  - Table 14 – Scratches After Paint.......10
  - Table 15 – Water Spots.......10
- Wet Mars.......11
- Bullseyes.......11
  - Table 16 – Wet Mars.......11
  - Table 17 – Bullseyes.......11

Index (cont'd)

APPEARANCE ZONES **12**
  Table 18 – Appearance Zones Pick-Up Trucks-Utility-Suburban-Vans-APV, LCF 12
  Preparation 17
    Painted Surfaces 17
    Unpainted Surfaces 17
PAINT SYSTEMS AND PROCEDURES **18**
  GM-Approved Refinish Materials 18
    The Bottom Line 18
  Undercoats 18
    Prepcoats (Etch Primers) 19
    Primer-Surfacers 19
    Primer-Sealers 19
    Sealers (Adhesion Promoters) 19
  Putties and Fillers 20
  Topcoat 20
  Basecoat 20
  Clearcoat 20
  Finesse/Clear and Polish 20
  Sanding (Primer) 20
  Moist Sanding 20
  Wet Sanding 21
  Ionizers 21

Index (cont'd)

REPAIR SYSTEMS **22**
- Sanding 22
- Repair Primer (Etch) 22
- Spot Repair 23
  - Sanding 23
  - Repair Primer 23
  - Color Coat 23
- Touch-Up Repair 23
- Spot Finesse Sanding/Polishing Basecoat 24
  - Clearcoat 24
  - Removing Defects 24
  - Sanding 24
  - Finesse Polish (Rotary) 25
  - Final Buffing (Orbital) 25

MANUAL SPRAY GUNS AND APPLICATIONS **26**
- Table 19 – Table of Parameters/Trends in Movement 28
- Solvent Rub Testing of Coats 29
  - Solvent Wipe Procedure 29
  - Table 20 – Solvent Rub Test Ratings 29

APPENDIX I **30**

Transit Coating 30

Properties 30

Transit Coating Application Matrix 31
- Fluid Delivery Rate 32
- Atomizing Air Pressure 33
- Dilution 34
- Gun Distance 35

Appendix I (continued)

Relative Gun Tip Speed (Conveyor Speed) 36
Ambient Air Temperature 37
Relative Humidity 38
    Maintenance and Cleaning 39
Lubrication of Gun Parts 39
General Spray Gun Assembly 40
    Air Adjustment Valve 40
    Fluid Adjustment Valve 40

APPENDIX II 41

APPENDIX III 44

Paints And Sealing

Sealants

A sealant is any organic material used to prevent air, dust, water or noise from entering the vehicle body. They come in a variety of forms, including:

- bulk pumpable
- thumbgrade
- extruded
- die-cut parts

A sealant's most important property is its bond strength; that is, its ability to adhere to the base material or "substrate" to which it is applied.

Sealant beads and their substrates are in constant molecular motion. This motion is the interplay of many forces of various magnitudes being applied from many directions. These forces may occur together or in any combination.

Sealants are primarily used on joints. The purpose of a joint is to carry a load or to transmit a load from one structural member to another. The point at which the load is transferred is called a joint.

Bonding Principles

The following general principles provide a clearer picture of how sealants work:

- In order for effective bonding to occur, a sealant must be applied to a solid base material. Attempting to bond to a weak substrate will result in failure between the layers. Loose rust, for example, is a weak substrate.
- Directly related to bond quality is the degree of molecular contact between the sealer and substrate. Wetting and diffusion of the sealer causes this contact. If wetting does not take place during application and curing, basic adhesion will not result.
- A variety of stresses (e.g. residual internal; thermal expansion and contraction; volumetric shrinkage or expansion; and environmental) act on the strength of a bond. Environmental stress, such as those produced by moisture or thermal cycling, have the greatest detrimental effects.
- Some common causes of poor bond formation are careless application, void in bond line, improper surface preparation, improper care and poor joint design.

! Primers sometimes act as adhesion promoters. For example, where wetting is inadequate, the primer may act as a wetting medium to the substrate. This enables the sealer to easily wet the substrate, transforming a poor bond to satisfactory. Primers may also work as a barrier, preventing environmental factors such as water or gases from [displacing] the sealer at bonding sites.

Reactive And Non-Reactive Sealants

There are two basic types of sealants: reactive or non-reactive.

- Reactive sealants actually undergo a change to their basic molecular structure during bonding. That is, they react chemically to such processes as oxidation or polymerization to form a bond.
- Non-reactive sealants develop their final form and properties by solvent evaporation or fusion of compatible components. They do not undergo any chemical changes; only changes to their physical form.

Paints And Sealing (cont'd)

Solvent Type Sealants

Solvent type sealants have two distinct advantages:

- They have a quick set-up time.
- They can be used at ambient temperatures.

One disadvantage, however, is that they tend to shrink as the solvent evaporates. This shrinkage may leave voids in the seal.

Air-dry sealants are designed to cure without baking. They are solvent-containing materials that crosslink and cure when these solvents evaporate. Their ability to cure without heat ideally suits them for use by vehicle converters.

For specific sealant and solvent information, see Appendix I of this manual.

Surface Preparation

Before applying sealant to any surface, take the following precautions:

- Make sure that all surfaces are free of oil and contamination. This will ensure proper adhesion.
- Use a clean cotton cloth and an alcohol-based solvent to wipe all areas.

Paint

The vehicle’s paint or “topcoat” has two primary functions:

- to provide an attractive appearance.
- to protect the primer layer (and subsequently the substrate) from physical environmental damage.

In other words, the color and luster of the topcoat are the main contributors to the vehicle’s overall appearance. The topcoat, however, also plays a key role in protecting the substrate and maintaining its durability. It acts as a barrier to ultraviolet light, which can deteriorate corrosion-resistant primers and plastic substrates. In addition, the topcoat provides resistance to abrasion and moisture.

Standards

Before any products are approved and released for production, they must meet appearance and durability performance standards. The Surface Appearance section of this manual describes the surface appearance and quality standards for every major body panel. See Appendix I for GM performance standards for the finish products described in this manual.

When preparing a surface for painting, follow these two general guidelines:

- Round off all pierced, drilled or cut edges to allow a uniform coating of paint as shown in Figure 1 (next page).
- Deburr areas that are too small to round off. This will eliminate them as potential corrosion sites.

Paints And Sealing (cont'd)

Standards (continued)

After cutting and rounding the edges, use the steps below to treat the bare metal area:

1. Using a clean cloth, solvent wipe with approved degreaser.
2. Coat all bare metal with an approved etch primer.
3. Recoat with a corrosion-resistant material such as a zinc-rich primer, Ziebart-type coating or corrosion resistant wax.
4. Recoat the vehicle's underbody with corrosion-resistant underbody primer or deadener. Be sure to cover all applied bolts and screws to ensure corrosion resistance.

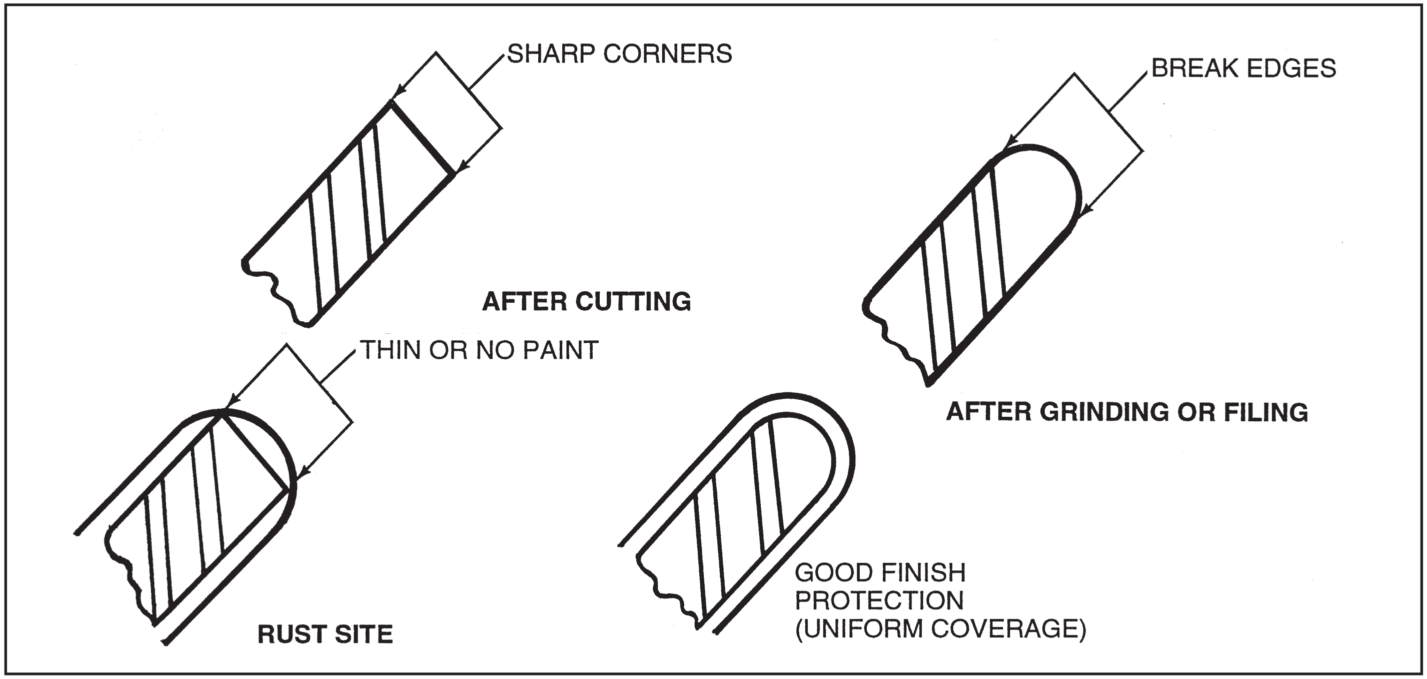

SHARP CORNERS
BREAK EDGES
AFTER CUTTING
THIN OR NO PAINT
AFTER GRINDING OR FILING
GOOD FINISH
PROTECTION
(UNIFORM COVERAGE)
RUST SITE

Figure 1

Surface Appearance

Surface Appearance

This section describes the surface appearance and quality standards for GM vehicles for each major body panel or "zone." The purpose of these requirements is to assure that the paint finish on GM vehicles meets or exceeds the quality level expected by our customers. The tables included throughout this section will help the SVM in meeting GM standards for painted body appearance and quality.

Appearance Zones

The body of a vehicle is divided into different appearance "zones". This enables us to separately define the distinct quality requirements of each zone. Table 1 (at right) describes the appearance zones.

Paint Audit Procedure

Listed below are the lighting requirements necessary to inspect the vehicle for specified surface characteristics:

- **Surface blemishes:** In the inspection area, the light intensity shall meet or exceed 100 maintained foot/candles. All horizontal and vertical fluorescent fixtures are to have cool white, 800 miliamp, high-output, 110 W bulbs.
- **Swirl marks and mottle:** Employ sodium lights per White Book/GM Facilities Guidelines, Volume II (Duro-Test, Sylvania or other which meets 400 W HID lamp, 5200 K, 91 CRI 2800 lumens).
- **Color evaluation:** For inspection of a sample or part; Samples available from: https://store.thierry-corp.com/store/

! Training programs are required to educate operators, monitors and managers in the techniques and acceptability standards of this specification.

Quality Requirements For Appearance Attributes

This section describes appearance attributes for painted and repainted surfaces. Refer to the tables throughout this section for specific information on appearance zone requirements for each attribute.

Distinctiveness Of Image (DOI)

- Distinctiveness of Image: This term refers to the mirror-like reflection of the painted surface.
- Method of Inspection: DOI meter (BYK Wavescan, 1.800.343.7721) shall be used.
- Measurement Required: Measure points within each major body panel in each zone. Average each panel and compare to specification.

! Do not take DOI measurements on a grained or contoured surface. Doing so may render false or inaccurate readings.

Table 2 (next page) shows appearance zone requirements for DOI.

Table 1 – Appearance Zones

Zone	Description
A	Horizontal exterior surfaces (i.e., hood, roof, deck lid quarters catwalk, fender catwalk, and "top" of a part which mates to a horizontal surface)
B	Vertical exterior surfaces above the wheelhouse opening (i.e., fender, door, quarter and deck lid waterfall)
C	Vertical exterior surfaces below the wheelhouse opening (i.e., fender, door, and quarter)
D	Door, deck lid and fuel door opening and inner
E	Motor compartment, rear end panel and luggage compartment
F	Non-top-coated surfaces

Surface Appearance (cont'd)

Table 2 – Distinctiveness of Image (DOI) Historical Ref. Number

Color Family	Minimum Zone		
Color Type	A	B	C
Non-Metallic, Dark Metallic	86	75	75
Medium Metallic Light Metallic	80	70	70
Special Metallic	70	60	60

Gloss

Gloss is the shininess or sheen of the painted surface.

- **Method of Inspection:** Glossmeter (20 degrees) as referenced in ASTM D523 (Gardner/Byk- Chemie, Humer or equivalent).
- **Measurement Required:** Measure points within each major body panel in a zone. Average each panel and compare to specification.

Do not take gloss measurement on a grained or contoured surface. Doing so may render false or inaccurate readings.

Table 3 (below) shows appearance zone requirements for gloss.

Table 3 – Gloss

Color	Minimum Zone			
Color Type	A	B	C	D
All	80	80	80	60

Orange Peel

A rough or wavy appearance of the painted surface is referred to as “orange peel.” This condition is so named because it sometimes exhibits a texture which actually resembles that of an orange peel.

- Method of Inspection: Visual examination and comparison with standard orange peel panels.

Table 4 (below) shows appearance zone requirements for orange peel.

Table 4 – Orange Peel

Zone	Minimum
A	7
B	6
C	5

Uniformity

Uniformity is the degree to which appearance is consistent over the entire vehicle, both within individual panels and between adjacent panels within a zone. The specifications for several appearance attributes are listed below:

- **DOI:** A maximum of 15 units difference is acceptable.
- **Gloss:** A maximum of 15 units difference is acceptable.
- **Orange peel:** A maximum of 2 levels difference is acceptable.
- **Color:** The color shall not vary from the Color Standard for Zones A, B, and C. A slight color difference from Standard is acceptable for Zone D.

Surface Appearance (cont'd)

Mottle

High degrees of metallic flake disorientation appear on the finished surface as blotchy, light and dark places. This condition is referred to as “mottle.”

- **Method of Inspection:** Visual evaluation and comparison to paint boundary samples.
- Appearance zone requirements for mottle are shown in Table 5 (below).

Table 5 – Mottle

Zone					Description
A	B	C	D	E	
OK	OK	OK	OK	OK	No mottle
OK	OK	OK	OK	OK	Slight mottle which is uniform over entire vehicle
NG	NG	NG	OK	NG	Excessive mottle

Paint Surface Blemishes

This section describes paint surface imperfections known as "blemishes." When combinations of different types of these blemishes are present, all shall be treated as being of the type which has the most severe requirements. The grouping must fall within the acceptance level specification for that type.

Paint Chips

Usually caused by scraping or impacts on the painted surface, paint chips are simply the absence of a small portion of the paint film.

- **Method of Inspection:** Visual examination and comparison with boundary samples (plant developed).

Appearance zone requirements for paint chips are shown in Table 6 (below).

! Quality touch-up on panel edge is acceptable if less than 3.0mm in diameter and no color change.

Craters

Craters are small round depressions in a paint film which may or may not expose the underlying surface.

- **Method of Inspection:** Metric scale and visual examination and comparison to boundary samples (plant developed).

Appearance zone requirements for craters are shown in Table 7 (below).

Dirt

Dirt is any foreign matter in, on, or under the paint film surface. Typical examples of dirt are lint, fibers and sanding dust.

- **Method of Inspection:** Metric scale and visual examination and comparison to boundary samples (plant developed).

Table 8 (below) shows appearance zone requirements for dirt in paint.

Table 6 – Paint Chips

Zone					Max Qty Zone	Max Size (mm)	Description
A	B	C	D	E			
OK	OK	OK	OK	OK	1	<1	No color change
NG	NG	NG	NG	OK	1	<1	No color change
NG	NG	NG	NG	OK	1	<1	Color change
NG	NG	NG	NG	NG	N/A	ANY	Substrate exposed

Table 7 – Craters

Zone					Max Qty Pnl/ Zone	Max Dia (mm)	Description
A	B	C	D	E			
OK	OK	OK	OK	OK	≤4	<1	Primer not exposed
NG	NG	NG	OK	OK	≥5	≤1	Primer not exposed
NG	NG	NG	OK	OK	≥1	ANY	Primer exposed
NG	NG	OK	OK	OK	≥1	≥1	Not exposed
NG	NG	NG	OK	OK	≥1	≥4	Not exposed

Table 8 – Dirt (In Paint)

Zone					Max Qty Pnl/ Zone	Max Size (mm)	Description
A	B	C	D	E			
OK	OK	OK	OK	OK	≤4	≤1.0	Same color
NG	NG	NG	OK	OK	≥5	≤1.0	Same color
NG	NG	OK	OK	OK	≥1	≥1.0	Same color
NG	NG	NG	OK	OK	≥4	≥1	Same color
NG	NG	NG	NG	OK	≥1	≥1	Contrasting color

Paint Surface Blemishes (cont'd)

Dings

A localized depression or protrusion in the surface which is visible after painting is classified as a ding.

- **Method of Inspection:** Visual examination and comparison to boundary samples.

Table 9 (below) shows appearance zone requirements for dings.

Table 9 – Dings

Zone				Size (mm)	Description
A	B	C	D		
NG	NG	OK	OK	<10	Visible in reflected fluorescent light
NG	NG	NG	OK	10-30	Visible in nonreflected fluorescent light
NG	NG	NG	NG	>30	Visible in nonreflected fluorescent light

Overspray

When a rough or gritty texture appears on the paint film surface, it is referred to as "overspray."

- **Method of Inspection:** Tactile (by touch) and visual examination and comparison to boundary samples.
- **Evaluation Rate:** To be evaluated at a fare such that zero discrepant vehicles are shipped from the assembly plant.

Table 10 (below) shows appearance zone requirements for overspray.

Table 10 – Overspray

Zone					Description
A	B	C	D	E	
OK	OK	OK	OK	OK	Overspray not visible on panel
NG	NG	NG	NG	OK	Different color overspray
NG	NG	NG	NG	OK	Any color overspray which has a gritty feel

Pinholes/Popping

Small holes in the paint film which seem to have been pricked by a pin are called "pinholes" or "popping." These imperfections are usually caused by trapped solvent or a porous substrate.

- **Method of Inspection:** Visual examination and comparison to boundary samples.

Table 11 (below) shows appearance zone requirements for pinholes and popping.

Table 11 – Pinholes/Popping

Zone					Description
A	B	C	D	E	
NG	NG	OK	OK	OK	Pops which are visible only when viewed at an angle

Polish Marks

Swirl marks or hazy marks which are visible when viewed in lighting as specified in 4.3.2 are called "polish marks."

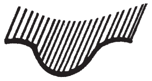
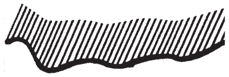
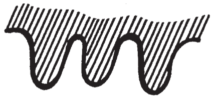
Paint Surface Blemishes (cont'd)

Sags And Runs

Table 12 shows appearance zone requirements for sags and runs.

! Runs on door edges are acceptable if less than 2mm long.

Table 12 – Dings

Illustration	Zone					Description
	A	B	C	D	E	
	OK	OK	OK	OK	OK	Very slight sag that is difficult to notice
	NG	NG	OK	OK	OK	One point sag, which is the same color
	NG	NG	OK	OK	OK	Run, same color
	NG	NG	NG	NG	NG	Three-point sag, or more, which is the same color

Painted Body Appearance

This section covers imperfections in the painted body appearance.

Sand Scratches

Improper sanding of the paint film or substrate can cause imperfections. They often appear as offcolor spots or lines and swirls which can either be seen or felt. Table 13 (at right) shows zone requirements for sand scratches.

- **Method of Inspection:** Tactile (by touch) and visual inspection and comparison to boundary samples (plant developed).

Table 13 – Sand Scratches

Zone					Description
A	B	C	D	E	
NG	NG	OK	OK	OK	Visible in reflected fluorescent light
NG	NG	NG	OK	OK	Visible in nonreflected fluorescent light

Scratches

The severity of scratches on the paint film surface can vary greatly as shown in Table 14.

- **Method of Inspection:** Tactile (by touch) and visual inspection and comparison to boundary samples (plant developed).

Table 14 – Scratches After Paint

Zone					Max Length (mm)	Description
A	B	C	D	E		
OK	OK	OK	OK	OK	20	Seen but not felt with the back of a fingernail (can be polished out with little effort)
NG	NG	OK	OK	OK	20	Slightly felt with the back of a fingernail
NG	NG	NG	NG	OK	N/A	Lower paint film is exposed
NG	NG	NG	NG	NG	N/A	Metal/substrate is exposed

NOTE: One per zone for Zones A, B, C and D.

Water Spots

Water spots may appear as circular blemishes on the paint film. They are usually caused by improper dry-off or a poorly deionized water rinse.

- **Method of Inspection:** Visual evaluation and comparison to boundary samples (plant developed).

Table 15 (at right) shows appearance zone requirements for water spots.

Table 15 – Water Spots

Zone					Max Qty Pnl/ Zone	Max Dist (mm)	Description
A	B	C	D	E			
NG	NG	OK	OK	OK	3	300	Visible in reflected fluorescent light
NG	NG	OK	OK	OK	3	300	Visible in nonreflected fluorescent light

Painted Body Appearance (cont'd)

Wet Mars

Disturbances that appear in the wet paint film prior to baking are termed "wet mars."

- **Method of Inspection:** Visual evaluation and comparison to boundary samples (plant developed).

Table 16 (at right) shows appearance zone requirements for wet mars.

Table 16 – Wet Mars

Zone					Max Length (mm)	Description
A	B	C	D	E		
NG	NG	OK	OK	OK	<10	Not easily detectable
NG	NG	NG	OK	OK	≥10	Easily detectable
NG	NG	NG	NG	OK	N/A	Primer exposed

Bullseyes

Bullseyes are uneven surface depressions which can be seen or felt on a panel. They usually result from improper sanding prior to painting.

- **Method of Inspection:** Tactile (by touch) and visual evaluation and comparison to boundary samples (plant developed).

Appearance zone requirements for this condition are shown in Table 17 (at right).

Table 17 – Bullseyes

Zone					Description
A	B	C	D	E	
NG	NG	OK	OK	OK	Visible in reflected fluorescent light
NG	NG	NG	NG	OK	Visible in nonreflected fluorescent light
NG	NG	NG	NG	OK	Can be felt

Appearance Zones

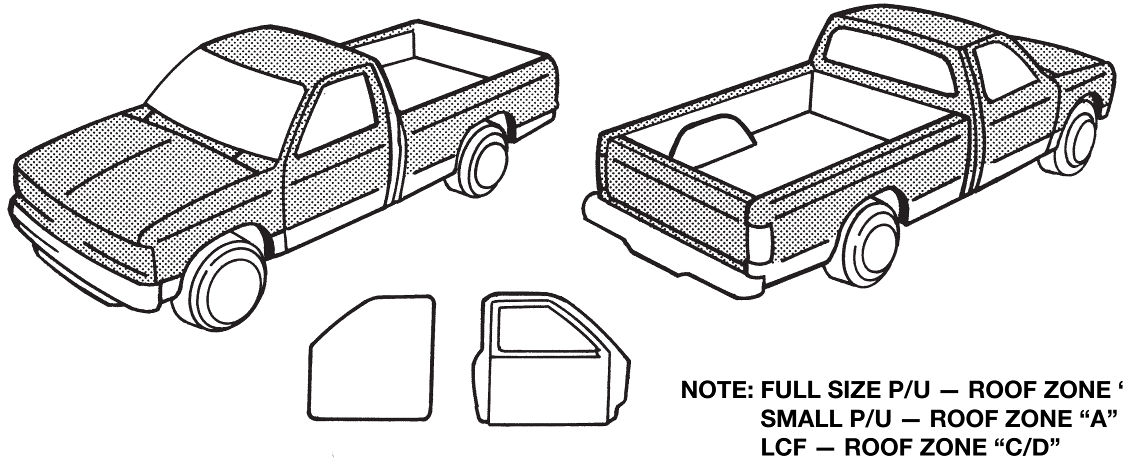
This section further defines and illustrates the vehicle's appearance zones. Because the different zones have varying degrees of visibility, they also have different appearance requirements. See Table 18 for descriptions of these visibility factors.

The illustrations that follow serve as paint/metal surface appearance guidelines for vehicle appearance zones on pickup trucks, utility, Suburban, vans and APVs.

Figure 2 shows appearance Zone A for pickup trucks. Appearance Zone A includes all horizontal exterior surfaces including the hood, roof, fenders, top pickup box (running boards), front and rear fascias; all vertical exterior surfaces above an imaginary horizontal line drawn between the top of the front and rear bumpers. Door inner belt/waist lines.

Table 18 – Appearance Zones - Pick-Up Trucks, Utility, Suburban, Vans, APV

ZONE "A" (Very High Visibility)	
EXTERIOR HORIZONTAL:	Hood, fenders, roof (small PU/utility only) front and rear fascia, top of box (running boards)
VERTICAL:	All surfaces above the horizontal line to the top bumper level
EXTERIOR:	Door inner belt/waist line "A" and "B" Pillars
ZONE "B" (High Visibility)	
Door openings and inner panels, exception made of of door hinge areas and lower side of door inner panel. All outside surfaces below the horizontal line to the top bumper level. All interior painted surfaces.	
ZONE "C" (Moderate Visibility)	
Front fender rails, tailgate inner panel, P/U box inner front end (tie bar), fuel filler opening, roof (full size P/U, utility, all vans and Suburbans)	
ZONE "D" (Low Visibility)	
Engine compartment, inner hood, door hinge areas on both side panel and door Door inner panel lower side	



NOTE: FULL SIZE P/U — ROOF ZONE "C"
SMALL P/U — ROOF ZONE "A"
LCF — ROOF ZONE "C/D"

Figure 2

Appearance Zones (cont'd)

Paint/metal surface appearance guidelines for appearance Zone B for pickup trucks is shown in Figure 3. Included are all vertical exterior surfaces below an imaginary horizontal line to the bumper level, wheels, door openings and inner panels, and all interior painted areas. Two exceptions are the door hinge areas and the lower side of the door inner panels.

Appearance Zone C includes front end (tie bar), front fender rails, roof pickup box inner (floor and sides), tailgate opening, tailgate inner panel, and fuel filler opening. These areas are shown in Figure 4.

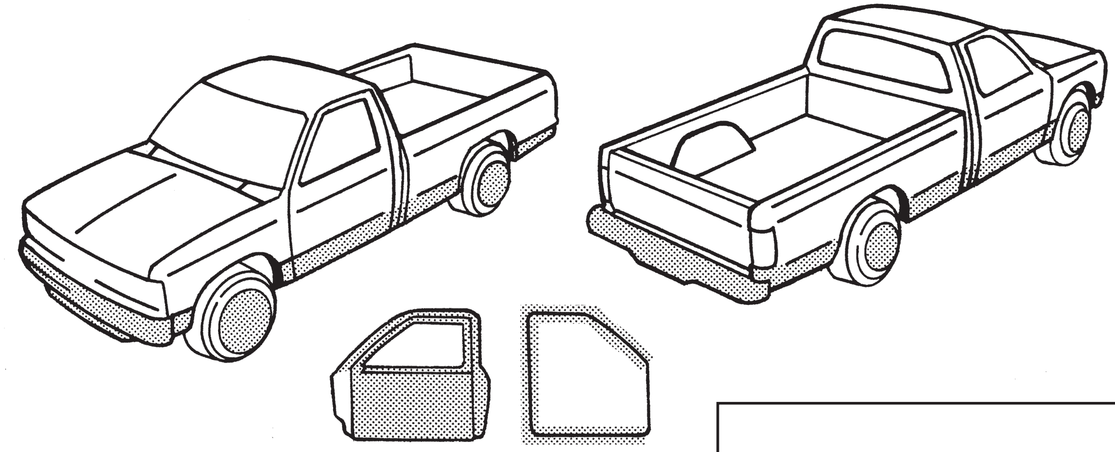
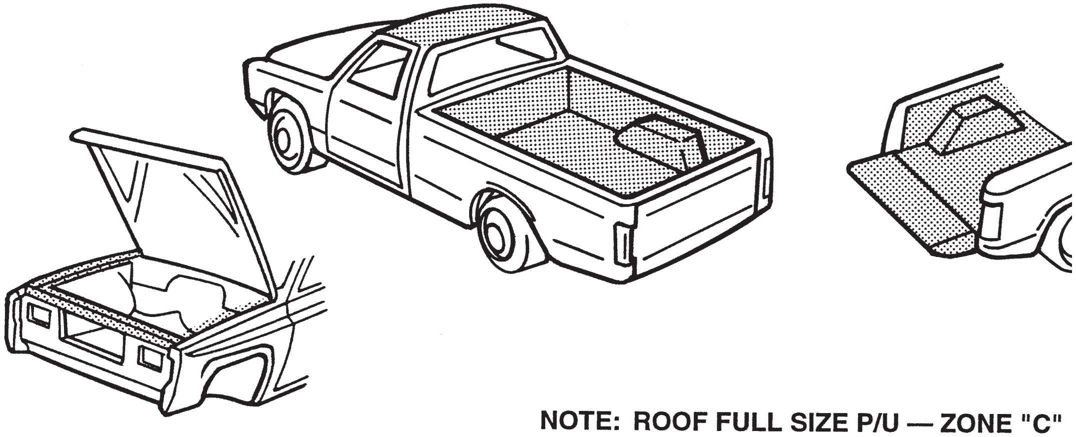


Figure 3



NOTE: ROOF FULL SIZE P/U — ZONE "C"
ROOF SMALL P/U — ZONE "A"

Figure 4

Appearance Zones (cont'd)

Figure 5 illustrates appearance Zone D for pickup trucks. This zone includes the engine compartment, hood inner panel, door hinge areas in door openings and door inner panels, and the lower side of the door inner panels.

Appearance Zone C for utility trucks includes the front end (tie bar), front fender rails and fuel opening. See Figure 6.

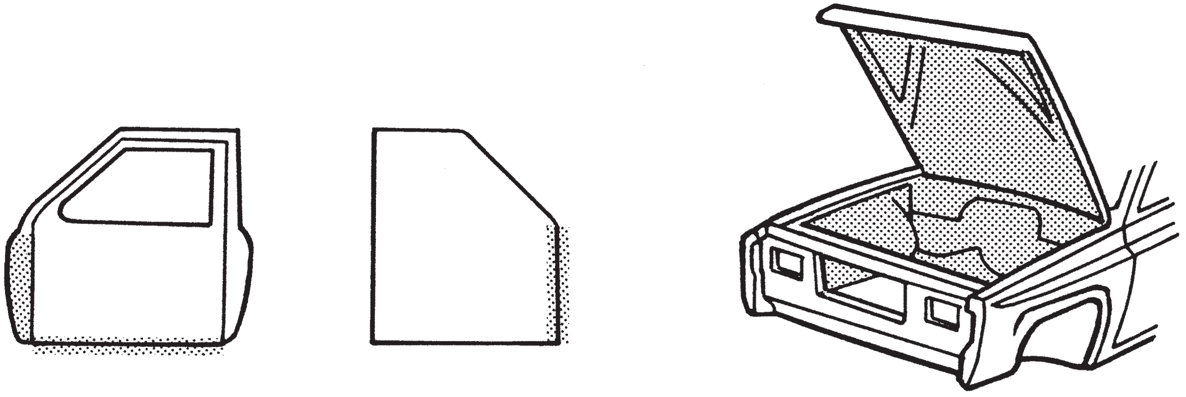
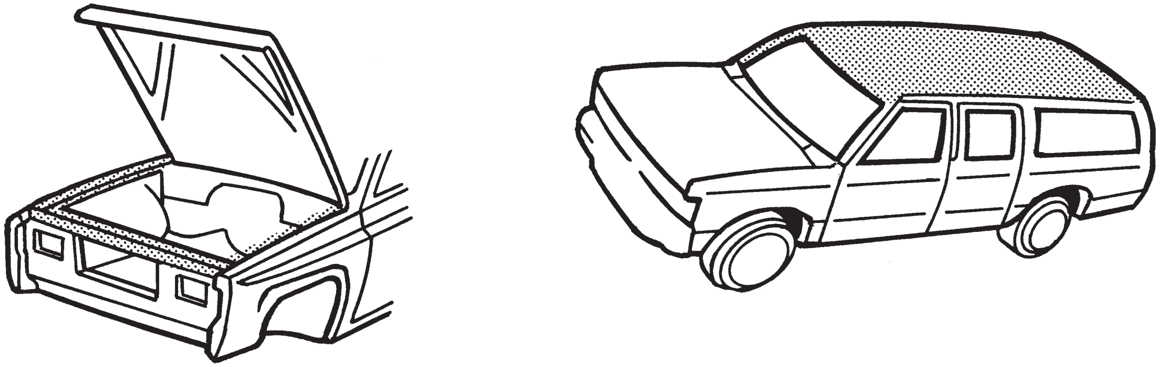


Figure 5



NOTE: ROOF FULL SIZE UTILITY/SUBURBAN — ZONE "C"
ROOF SMALL UTILITY — ZONE "A"

Figure 6

Appearance Zones (cont'd)

Appearance Zone D for utility trucks includes the engine compartment, hood inner panel, door hinge areas in the door openings and door inner panels and the lower side of the door panels. These areas are shown in Figure 7.

For vans, APVs and LCFs appearance Zone A includes all horizontal exterior surfaces including the hood, fenders, front and rear fascias; all door inner belt/ waist lines; and all vertical exterior surfaces above an imaginary horizontal line drawn between the top of the front and rear bumpers at the bumper level. These areas are defined in Figure 8.

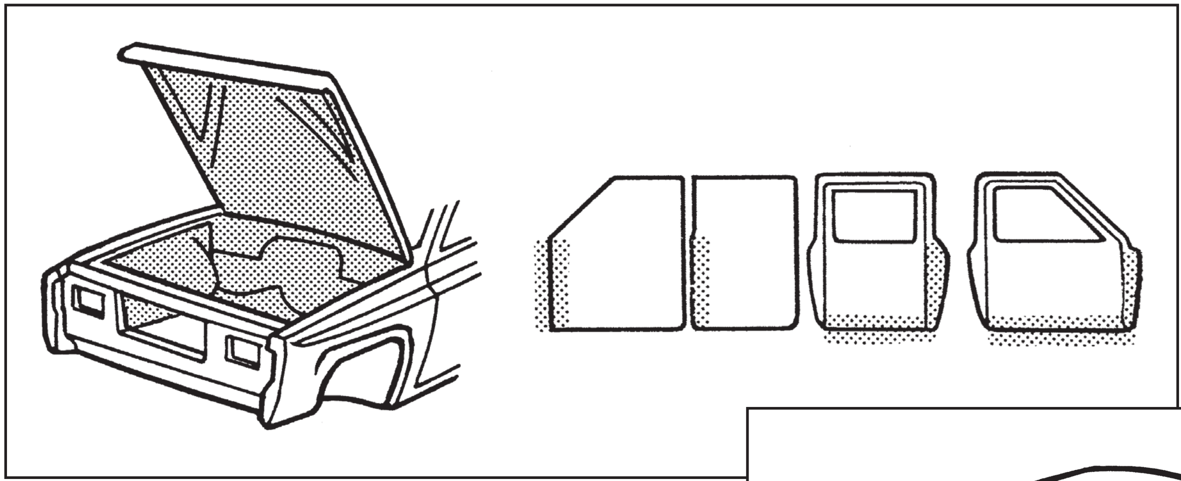


Figure 7

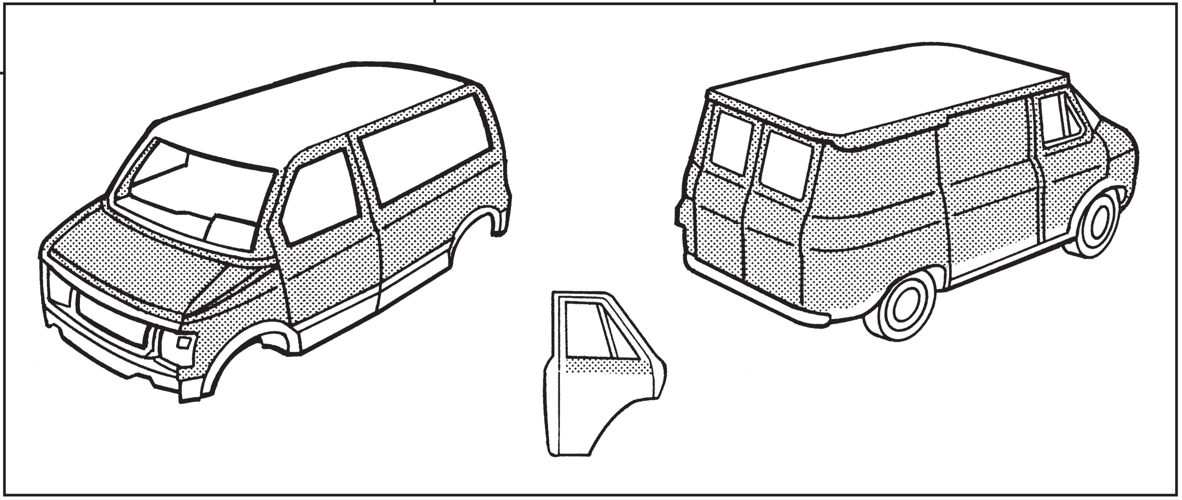


Figure 8

Appearance Zones (cont'd)

Figure 9 shows appearance Zone B for vans and APVs. It includes all vertical exterior surfaces below an imaginary horizontal line drawn at the bumper level: wheels, door openings and inner panels, all interior painted surfaces and roof (YF7 option). Not included in Zone B are door hinge areas and the lower side of the door inner panels.

The front end (tie bar), front fender rails, roof, and fuel filler opening make up appearance Zone C for vans and APVs. These areas are illustrated in Figure 10.

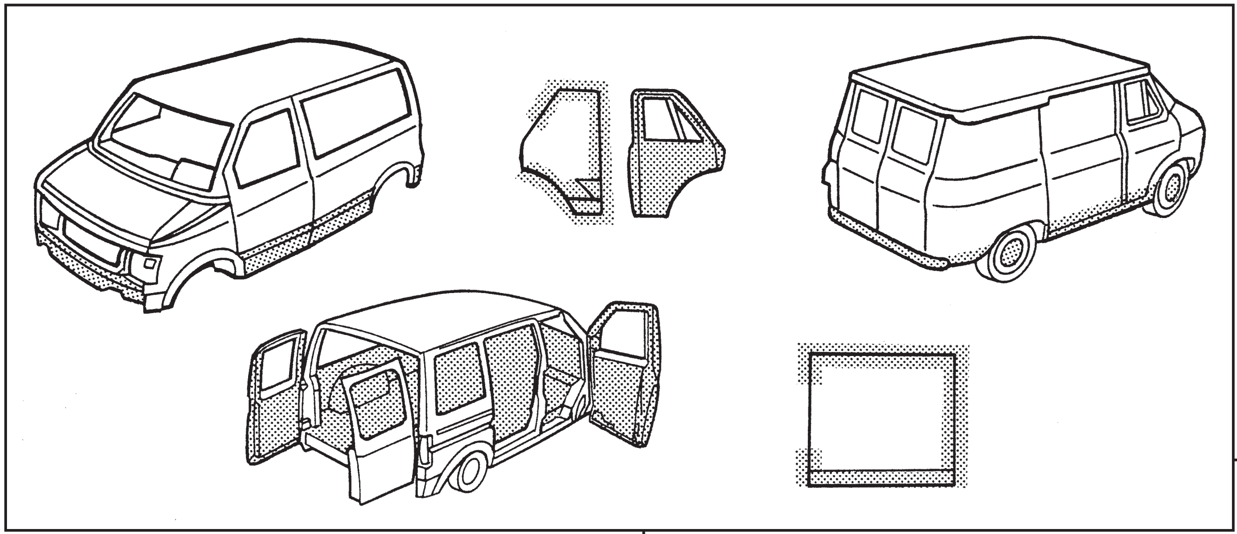


Figure 9

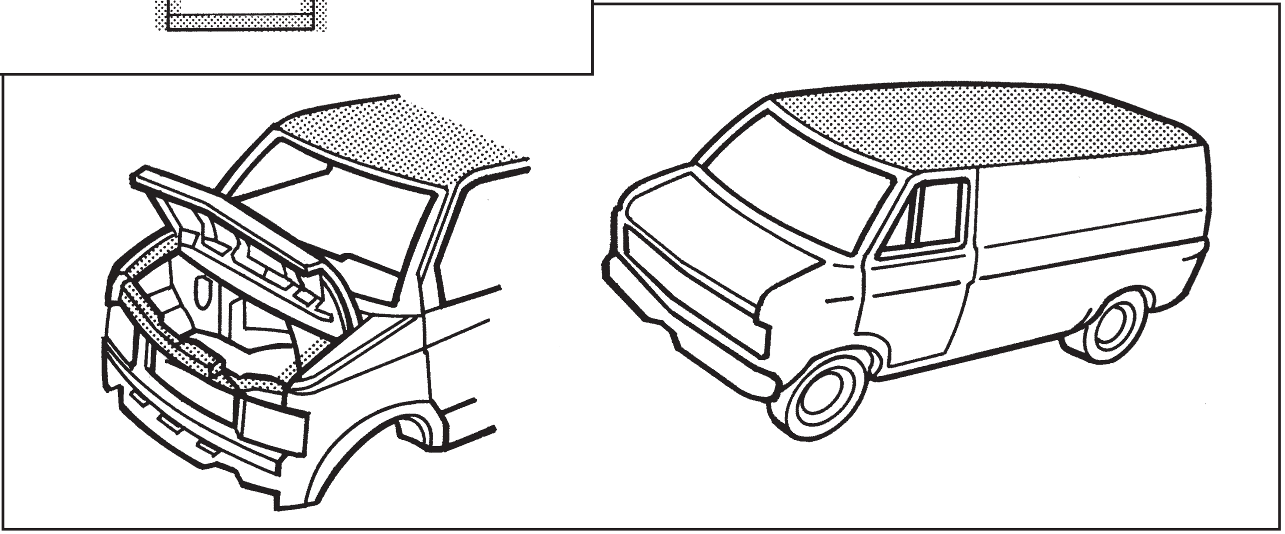


Figure 10

Appearance Zones (cont'd)

Zone D for vans and APVs includes the engine compartment, hood inner panel, door hinge areas in the door openings and inner panels, and the lower side of the door inner panels (front, side, rear). Figure 11 shows these areas.

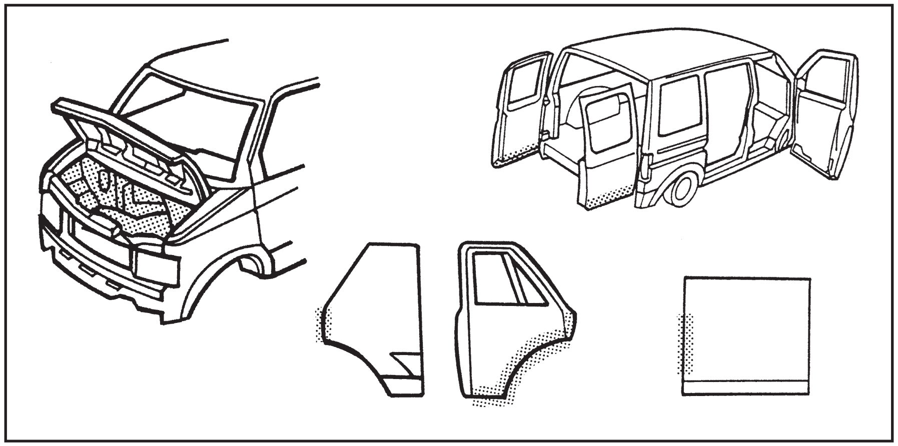


Figure 11

Preparation

A good paint job requires proper surface preparation. The weak base resulting from poor preparation eventually results in the overall failure of the finish. This section describes preparation for two types of surfaces:

- previously painted
- bare substrate

Painted Surfaces

The steps below describe the preparation for painted surfaces:

1. Wash the painted area thoroughly to remove as much contamination as possible. This will also eliminate dust and dirt.
2. When applying a new finish over an old one, solvent clean the old finish. This removes wax and other contaminates that can harm the new finish and cause loss of adhesion.
3. Fold a clean, dry cotton cloth. Soak it with a solvent (see General Motors specifications for solvents) made expressly for this purpose and apply to the old painted surface. While the surface is still wet, fold a second clean cloth and wipe dry. Work small areas so the surface can be wiped clean before it dries.
4. Measure and record the original film thickness before sanding. This ensures that maximum total film builds of 11 mils for OEM (14 mils with powder prime) and 12 mils refinish are not exceeded.

! Use an electronic paint gauge to measure film thickness. Consult Appendix III of this manual for additional information.

! After sanding or grinding, it may be necessary to further clean the surface prior to any filling or painting.

Unpainted Surfaces

Proper metal treatment is critical to the success of every painting operation. Poor adhesion and corrosion can result when the surface is treated improperly or carelessly. Always chemically clean bare metal surfaces to ensure optimum adhesion for the undercoat.

Paint Systems And Procedures

GM-Approved Refinish Materials

General Motors continuously pursues quality improvement. Therefore GM has established automotive refinishing standards for itself as well as its Marketing Division Dealers and Retailers. GM is the first domestic car company to set a specification for aftermarket paint finishes.

GM has established standards for paint refinishing. Each Division requires the Dealer to use only materials and methods that meet GM Standard GMW15406 when repairing, replacing, or refinishing vehicles. Where it is determined that the Dealer is using paint systems or materials which do not meet GMW15406 standards, appropriate counsel and/or corrective action may be taken.

The Bottom Line

The Dealer or Retailer must ensure that all finish repairs, including sublets, meet GM Specification GMW15406. Use of materials (and associated methods) that do not meet this GM standard may result in a review of claim(s) leading to chargeback(s).

As warranty periods increase, customer expectations continue to rise. Many Dealers/Retailers understand customer expectations. As a result, they have chosen a single, complete system approach and only use the systems that meet the highest standards of quality and durability.

All the paint manufacturers that meet the GMW15406 Specification have spent thousands of manhours in research and development to ensure the approved system gives the appearance, performance, and durability comparable to the OEM finish. The products in the systems listed in this book are the very best products to use. They are guaranteed to produce the consistent, quality results that GM customers expect. This makes it easier for you, as the Dealer/Retailer, to confidently choose a system that will maximize your customers' satisfaction.

Each year, all new paint systems will be tested and evaluated. New or improved products will also be tested. The paint systems that pass this annual testing process will be published in this booklet, updated annually.

For further information on these systems can be found at:
http://www.genuinegmparts.com/for-professionals/collision-repair-manuals

If booklets are needed, call 1-800-269-5100.

See Appendix II of this manual for additional information for GMW15406 standards and approved sources.

Undercoats

Like surface preparation, proper undercoating is necessary to achieve an attractive, durable topcoat. It is important to use the right undercoat for the job and to apply it promptly following surface preparation.

There are four types of undercoats:

- Prepcoats
- Primer-surfacers
- Primer-sealers
- Sealers

Paint Systems And Procedures (cont'd)

Prepcoats (Etch Primers)

Prepcoats prepare the bare metal substrate to accept and hold the color coat. They do this by providing adhesion to the surface and producing a corrosion-resistant foundation. Prepcoats do not fill well and are used in conjunction with a primer-surfacer.

Self-etching prepcoats provide excellent adhesion. Also used as prepcoats are zinc chromate primers, which protect steel and aluminum against rusting or corrosion. Prior to assembly, a coat of this primer can be sprayed where dissimilar metals contact each other. This prevents the electrolytic action that causes rapid corrosion of the metal.

Primer-Surfacers

Applied prior to basecoat clear coat application, primer-surfacers build up the base required for sanding. GM recommends two applications of primer-surfacer, with the second application color keyed to topcoat.

Good primer-surfacer characteristics are:

- The ability to create a strong bond or adhesion between the substrate and the applied topcoat.
- Corrosion resistance to prevent disintegration of the metallic substrate.
- The ability to “build” or cover all surface imperfections (i.e., grind marks, sand scratches, etc.).
- Ability to sand smoothly and level quickly and easily.
- “Hold out” or sealing quality to prevent the topcoat from “striking” into the film causing a dull look.
- Quick drying speed, allowing sanding within a reasonable time.

Always measure primer quality per GM specification GMW15406.

Primer-Sealers

Primer-sealers provide the same protection as prepcoats: adhesion and corrosion resistance. They also have the ability to seal a sanded old finish to provide uniform color hold-out.

Primer-sealers can be used to prime a bare surface and as a sealer under any enamel topcoat.

Sealers (Adhesion Promoters)

Sealers perform three basic functions:

- Improve adhesion between the old finish and the new
- Provide uniform color background and holdout for the topcoat
- Provide a solvent barrier to help prevent sandscratch swelling and show-through

! Unlike primers, sealers are sprayed over prepcoats, primer surfaces, or sanded old finishes.

Clearcoat areas must be sealed prior to repainting.

- Sealers are not used as primers. They are sprayed over prepcoats or primer surfaces, or sanded old finishes.
- Before applying a sealer, all surfaces must be thoroughly scuff-sanded (no glossy areas). This prevents delamination.

Paint Systems And Procedures (cont'd)

Putties And Fillers

Putties and body fillers (while not precisely undercoats) can be termed “solid” undercoats.

- A putty is a paste and has a much heavier body than a primer-surfacer. It is used to fill any small imperfections or flaws remaining in the substrate after primer-surfacer has been applied. Putty must be sanded.
- Body fillers are an extremely durable polyester plastic material that sands smooth after drying. It is used to fill large flaws before either primer or putty is applied.

Topcoat

From the customer’s standpoint, the topcoat is the most important step in the painting operation. This is because the customer sees only the topcoat and judges the quality of the entire paint job on its appearance.

Basecoat

The first step in color matching is to select the proper topcoat color. Paint quality and durability must meet the requirements of GM specification GMW15406 (refinish materials).

Clearcoat

Clearcoat quality must meet the requirements of GM specification GMW15406. A minimum thickness of 1.5 mils is necessary to protect the finish from ultraviolet penetration.

Accurate measurements of the clearcoat application ensures that the 1.5-mil minimum film-build is maintained. An OEM finish finessed to match the surface of the newly painted area must be accurately measured before and after finesse to ensure that 1.5 mils minimum of clearcoat remain on the unit (0.5 mil maximum clearcoat removal). See Appendix III of this manual for film thickness measuring device.

Finesse/Clear And Polish

Accurate measurements of the clearcoat application ensures that the 1.5-mil minimum film-build is maintained. An OEM finish finessed to match the surface of the newly painted area must be accurately measured before and after finesse to ensure that 1.5 mils minimum of clearcoat remain on the unit (0.5 mil maximum clearcoat removal). See Appendix III of this manual for film thickness measuring device.

Sanding (Primer)

Sanding removes defects from a surface and prepares it to receive a topcoat. Two methods are moist sanding and wet sanding. Great care must be taken with either method to avoid sand-through, which will adversely affect the appearance and durability of the finished product.

Before any detail or hand-sand operation, it is important to classify exterior body panels as Zone A, B or C. Sharp edges or surface profiles not accessible by mechanical sanding should have an 8- to 12-mil gap between those areas and the areas sanded, as required. This gap range should always be detailed by hand.

Sanding through the primer surface or electro-deposited primer is not acceptable. These important layers guard against accelerated corrosion and paint failure.

Moist Sanding

Moist sanding is one method of defect removal which is preferable to the more labor-intensive operation of complete wet sanding. It allows the operator to inspect the surface for visible defects — such as dirt and sags — prior to painting. Moist sanding should be performed in an enclosed booth to avoid contaminating the entire paint shop with sanding residue. Compatibility of the primer with water must be verified with the supplier.

Paint Systems And Procedures (cont'd)

Moist Sanding (cont'd)

The general sanding process follows:

1. Cool units to below 37.8°C before sanding.
2. Use sandpaper with ANSI 400 grit or higher so that defects can be removed without producing sand scratches that are visible after topcoat application. If sand scratches are visible, reprocess with finer-grit sandpaper.
3. Thoroughly soak sandpaper prior to use. Spray area to be sanded with water to lubricate the work surface.
4. Remove the defect by sanding in a circular motion. This prevents uni-directional sand scratches.
5. Once the defect is removed, wipe the surface with a clean, lint-free cloth.
6. After removing all defects from the unit, wipe the entire surface with a 50/50 isopropyl alcohol/water mixture. This should remove any contamination that remains after moist sanding.

Tack-off, followed by air blow-off, must be completed before applying the next coat.

Wet Sanding

Depending on the surface contour, type of primer, and detail requirements of the unit, wet sanding may be preferable to mechanical methods.

The known hardness of the surfaces to be sanded and the surface profile of the unit determine the selection of equipment and materials (screen-cloth grit and size). Selection criteria should include (but not limited by) evaluation of sand scratches which result from the process and are not visible after topcoat application.

Maintaining a sufficient amount of water is critical to wet sanding. This avoids uneven cutting of the unit surface. After the last wet sand operation, a high-pressure rinse is required to remove all excess surface contamination that could affect the topcoat or its durability. A final rinse of deionized (DI) water should follow to remove all salts or foreign materials that affect topcoat quality.

When wet sanding by mechanical methods, always use multiple, uniform cuts on horizontal and vertical surfaces. This ensures that wet sand screen swirl cuts and other defects are not visible after topcoat application. Rinse screens as often as necessary with water to free any wet sand residue or abrasive particles that may lodge within the screen itself.

Ionizers

Sanding, finesse, detailing, tack-off and other assembly plant operations may deliver a static charge to the unit. The static charge in turn is a potential attraction for dirt or other surface contaminants. Ionizers are used to neutralize static charges. It is acceptable to use an ionizing air blow-off to blow dust, dirt and sanding particles from the unit. This process reduces static and imperfections in subsequent painting applications.

Repair Systems

Paint defects which do not meet minimum GM Surface Appearance Standards, as determined by comparison to previous charts, should be repaired using the methods outlined in this section. Key Process Controls should be established to ensure that only a minimum of production requires paint repair.

- Defects in enamel which cannot be removed by buffing or polishing must be sanded thoroughly and repainted. Repaint only the defective panels. Avoid repainting entire units. The total refinish system, including topcoat filmbuild, should not exceed 12.0 mils (11 mils for OEM or 14 mils with powder prime).
- Use pressure-sensitive masking tape and masking paper to mask off panels that do not require repair.

! A panel is an area bordered by molding edges, ornaments or a natural breakline which serves to hide the demarcation line between the repair paint and the original finish. Do not mask along a line in the middle of an open area. If necessary, multiple areas must be repainted. If the masking line becomes objectionable at any point, the condition can be alleviated by light sanding, buffing and polishing.

Sanding

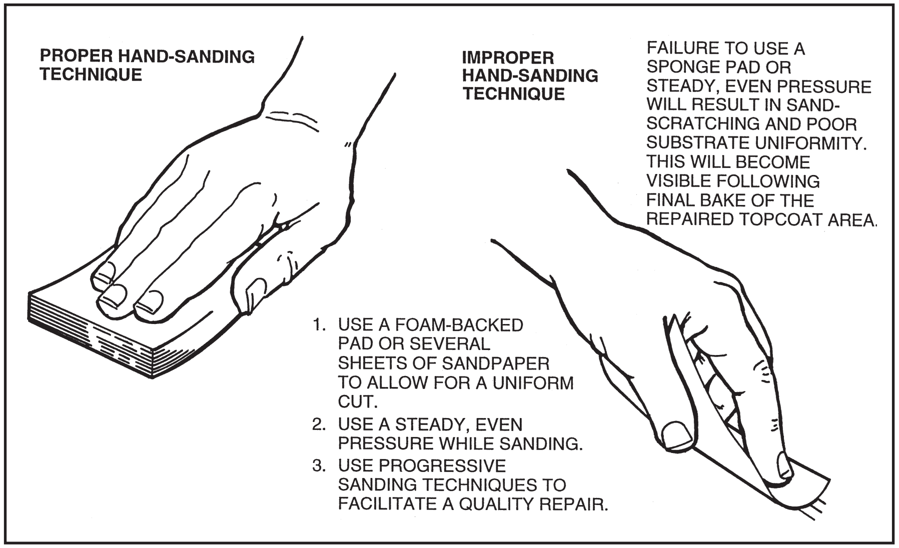
Remove any film irregularity by block sanding with ANSI 400 or 600 grit paper. It is necessary to scuff-sand the complete surface to be painted to avoid surface conditions that could adversely affect intercoat adhesion. Always give special attention to panel feature lines and depressions during scuff-sanding. After sanding, lightly wipe the entire panel surface with a tack cloth to remove sanding residues. See Figure 12 for proper hand sanding technique.

Repair Primer (Etch)

A coat of cut-through repair primer must be applied to all areas in which sanding has exposed the bare metal. Follow all supplier application parameters to ensure that all required properties are achieved.

Apply two layers each of basecoat and clearcoat using spray parameters given for main color application. Repair of clearcoat over clearcoat tends to be more sensitive to intercoat adhesion failures. Full sanding of clearcoat is mandatory prior to recoating with clearcoat.

! The repaired panel should match the original color and overall appearance as closely as possible.


PROPER HAND-SANDING TECHNIQUE
IMPROPER HAND-SANDING TECHNIQUE

FAILURE TO USE A SPONGE PAD OR STEADY, EVEN PRESSURE WILL RESULT IN SAND-SCRATCHING AND POOR SUBSTRATE UNIFORMITY. THIS WILL BECOME VISIBLE FOLLOWING FINAL BAKE OF THE REPAIRED TOPCOAT AREA.

1. USE A FOAM-BACKED PAD OR SEVERAL SHEETS OF SANDPAPER TO ALLOW FOR A UNIFORM CUT.
2. USE A STEADY, EVEN PRESSURE WHILE SANDING.
3. USE PROGRESSIVE SANDING TECHNIQUES TO FACILITATE A QUALITY REPAIR.

Figure 12

Repair Systems (cont'd)

Spot Repair

Full panel repair can be avoided if the defect is isolated in size and location. Spot repairs do not work well in the center of a vertical or horizontal surface and may not be applicable to all colors (e.g., high metallic).

Repairs are more difficult to detect if they are ended along a feature line or panel edge. This method camouflages the differences between the OEM finish and the spot repair.

CAUTION It is critical to apply clearcoat within sanded areas only. Recoat does not adhere to unsanded high-bake clearcoat.

Sanding

Spot repairs require sanding the defect and the surrounding area to which basecoat and/or clearcoat will be applied. Use a grit size no coarser than ANSI 400 to 600 grit for final sanding. This reduces the chance of sand scratches telegraphing through the repair topcoat. Feather out approximately 5 or 6 inches from the defect area with ANSI 1200 to 1500 wet grit paper to facilitate the final finesse operation. Wipe off all sanding residue with a clean, lint-free towel dampened with naphtha or 1:1 water/isopropyl alcohol. Tack off.

Repair Primer

Apply repair primer-sealer to sand-through area only, using a gravity-feed cup gun. The recommended dry film thickness is 1.0 to 1.5 mils.

Hand sand with moist ANSI 400-600 grit paper to promote topcoat adhesion. To avoid the telegraphing of sand scratches, do not sand outer area of repair previously sanded with ANSI 1200/1500 grit paper.

Color Coat

Color is applied to essentially three zones which feather into each other:

- Basecoat and clearcoat are applied to the defect area, which has been previously primed.
- Full clearcoat is applied beyond the basecoat and feathered.
- When topcoat application is completed, a halo of ANSI 1200-1500 grit-sanded area surrounding the repair must remain because clearcoat will not adhere to unsanded original clearcoat.

Polishing is required to blend the repair area with the surrounding panel. The original clearcoat, ANSI 1200-1500 grit-sanded area at the periphery, and the repaired area must all match in color and appearance. Optimal for appearance and gloss match is to clear coat entire panels when possible.

Touch-Up Repair

Use air-dry touch-up materials to repair minor chips and scratches only in those areas where appearance quality is not compromised (that is, on secondary surfaces and partially hidden edges). Never perform touch-up repairs within exterior body panels or on chips and scratches that have exposed bare metal.

Apply repair material only to the damaged area with minimal overlap onto the surrounding area.

! Some metallic colors require a clear touchup paint in addition to the color coat.

! Lacquer-type materials do not adhere to enamel clearcoats without sanding and use of primer-sealer.

Repair Systems (cont'd)

! Application of up to three coats (sealer, color coat and clearcoat) requires considerable finesse to obtain acceptable appearance. Some polishing may also be required.

! Enamel-type touch-up materials are preferable.

Some general guidelines for touch-up repairs are:

- Clean the area surrounding chip or scratch with naphtha to remove any grease, oil or other contaminants. Wipe dry with a clean, dry, lint-free cloth.
- If application of repair material is limited to mutilated area, it is not necessary to sand or apply primer to obtain adhesion.
- If repair material is applied to adjacent area (1/8 inch maximum), apply a light coat of primer-sealer to the repair area. Do not apply sealer to areas which will not receive repair paint. Alternately, the adjacent area may be sanded with ANSI 600 grit sandpaper, followed by ANSI 1200 grit sandpaper. This allows polishing to remove sanding scratches if required.
- Apply sufficient color coat to achieve hiding and color match before applying clearcoat.
- Nominal film-builds are 1.5 to 2.0 mils.
- If necessary to blend repaired spot with surrounding area, allow to air dry for 24 hours (or equivalent using heat source) and finesse polish.

Spot Finesse Sanding/Polishing Basecoat/Clearcoat

This process can be used to repair minor scratches, dirt, dull spots and related defects in the clearcoat without resorting to repainting. It may be performed before or after repairs. Do not use this method to repair major defects such as large sags, solvent pops, craters or basecoat defects.

Prior to finesse and repair, inspect the body for all paint defects in a well-lighted area (100 foot-candle lighting minimum). Use this method only on paint which is sufficiently cured and has cooled to 100ºF or below. Otherwise, objectionable swirl marks and other appearance deficiencies may result. Be very careful during each step of the process to remove as little of the clearcoat as possible.

Removing Defects

The approved method for removing defects, such as dirt protruding above the clearcoat surface, is by hand-planing with a file. You may attach a wood block to the file to facilitate the operation. Grasp the tool firmly. Gently shave the imperfection, using several strokes in one direction only.

CAUTION Apply minimum pressure and concentrate in the area of the defect only to avoid removing the surrounding clearcoat.

Clean and sharpen the file periodically to achieve proper defect removal.

Sanding

After removing the defect, lightly hand-sand the area. Use a special finesse sanding block with ANSI 1200 or 1500 grit paper and lubricating fluid. Use a circular motion, applying minimum pressure to avoid deep scratches, until defect is uniform with surrounding area. After sanding, wipe the affected area with a clean, lint-free cloth.

Repair Systems (cont'd)

CAUTION Do not sand excessively around the defect area. Reducing the clearcoat's thickness will affect durability.

! A minimum of 1.5 mils clearcoat must remain (0.5 mil maximum removal). Otherwise, the affected area must be recoated.

Finesse Polish (Rotary)

Follow the steps below to remove any fine scratches created by sanding:

1. Apply one 3/8 inch drop of specific finesse polishing compound per sanded spot.
2. Using a polish pad, evenly smear the compound over the sanded area before running the wheel.
3. While running the wheel, keep the pad flat, directly over the sanded spot. Operate the tool with a 1- to 2-inch circular motion to randomize the swirl pattern. Apply only enough pressure to maintain uniform contact with the surface. Polish panel edges and sharp contours lightly to avoid cut-through.

Inspect the polished area. Apply more polish, repeating as needed. When all sand scratches have been removed and the finish is uniform and glossy, the unit is ready for buffing. There is no need to remove polish residue.

Final Buffing (Orbital)

Final orbital buffing removes any swirl marks left by rotary polishing.

Apply additional finesse polishing compound or specified finesse buffing compound to each polished spot. Using an orbital buffing wheel, evenly smear the compound over the polished spot before operating the wheel. Begin buffing in the center of the swirl pattern. Use a slight back-and-forth motion and buff approximately 3 inches beyond the pattern. This will blend the refinished spot with the surrounding area.

Apply enough pressure to prevent free motion of the motor. Do not restrict the motor's dual action. This action helps to minimize the objectionable continuous swirl pattern.

After buffing, mist the area with 50/50 water/ isopropyl alcohol blend. Wipe with a soft cloth to remove polish residue. Inspect the surface under sunlight or sodium vapor lights. If it is not uniform and free of swirls or haze, repeat the buffing operation.

Manual Spray Guns And Applications

This section covers proper techniques for applying paint by hand. It is for informational purposes only. Major suppliers provide training in the proper spray application of their products. Specific questions should be addressed to them. See Appendix I of this manual for information on hand spray- gun operation and maintenance.

Good hand spraying technique (Figures 13, 14, and 15) ensures a uniform surface of specified gloss, DOI, texture, film-build and color. Proper technique requires attention to many elements, including:

- fluid delivery settings
- application stroke overlap and length
- triggering points
- spray pattern adjustment
- surface contour
- paint material characteristics
- film-build requirements
- hand gun-to-work orientation and distance

Several trial sprays may be necessary to establish an ideal, repeatable technique. The following table (Table 19) outlines topcoat process controls by describing the relationship between application parameters and appearance or performance attributes for typical processing situations. Parameters are often interdependent. That is, changing one can influence another. Many of the “typical” cases indicate general trends only for specific parameters.

Color is directly related to pigment strength, pigment loading, and degree of dispersion and metal flake orientation. Metal flake orientation is the area most influenced by application parameters. The orientation of metal determines how much pigment is exposed. See Figure 16 (on page 29).

- Lighter colors are produced when more aluminum and less pigment is exposed.
- Darker colors result from more aluminum disorientation.
- High degrees of metal disorientation cause blotches, light and dark patches commonly referred to as “mottle.”
- Two factors influence metal orientation:
  - — the kinetic energy of the paint particle striking the work place.
  - — the on-panel viscosity of the applied paint film.

Energy of the striking particle determines the initial metal configuration. The flow of film and evaporation of solvents determines the degree of aluminum or mica movement in the film. Generally, the lower the on-panel viscosity (i.e., wetter film), the darker the color. The higher (drier film) the on-panel viscosity, the less disorientation of metallic flake and the lighter the color.

Two processes compete in achieving desirable appearance:

- A good wet film assures good flow. The good flow of a paint film prevents “orange peel.” This condition tends to scatter light and reduce DOI.
- At the same time, the movement of aluminum or mica should be restricted to prevent dark color or mottling, which requires a drier film.

At this point the proper split-up of coats can solve the problem. Applying an initial wet coat assures good flow. Following this with a drier second coat assures good metal orientation.

CAUTION Make sure that the initial coat is wet enough to allow good fusion of the two coats; but not so wet that solvents quickly migrate into the final dust coat causing metal disorientation from over-fusion of the coats. See Figure 13 (next page).

Manual Spray Guns And Applications (cont'd)

In order to obtain repeatable results in both color and flow, it is necessary to control the environment. As discussed earlier, many factors (i.e., variable air velocity, booth temperature, paint temperature, humidity and body temperature) affect the final finish. That is, changes in any of the above results in the evaporation rate of solvents. This in turn affects color and flow of the applied paint. These variables cannot be totally controlled. Some drift from morning to afternoon and season can be expected in both color and film tightness.

This final spray determines solvent wetness and balance of coats. It requires a professional painter. The best method for spraying with a given paint system is best determined by trial and observation.

Refer to the Table 19 for parameters and trends in movement.

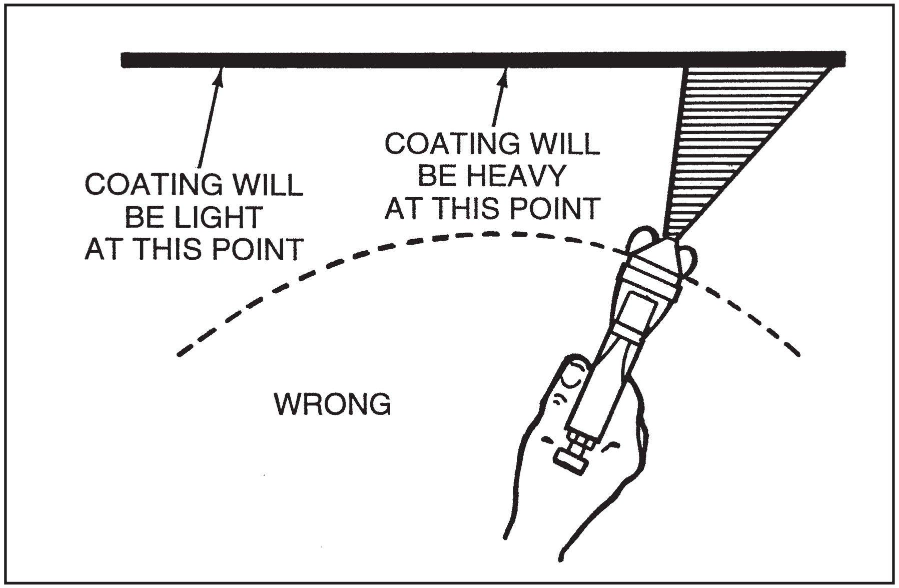

COATING WILL BE LIGHT AT THIS POINT
COATING WILL BE HEAVY AT THIS POINT
WRONG

Figure 13

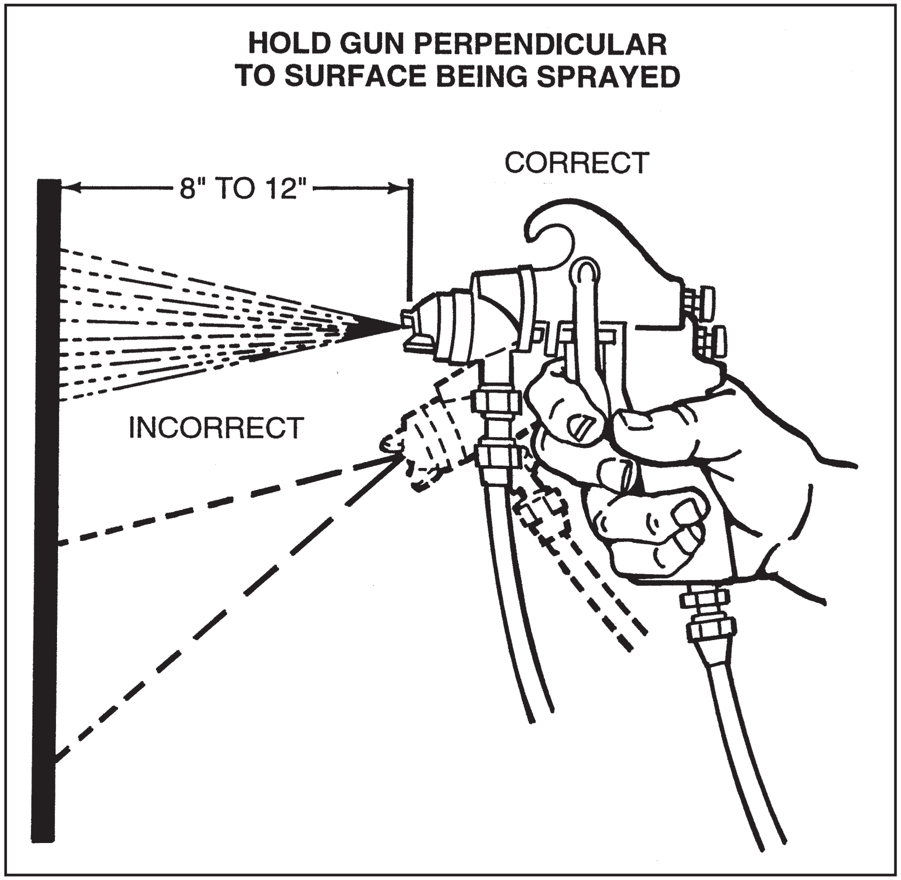

HOLD GUN PERPENDICULAR TO SURFACE BEING SPRAYED
CORRECT
8" TO 12"
INCORRECT

Figure 14

Manual Spray Guns And Applications (cont'd)

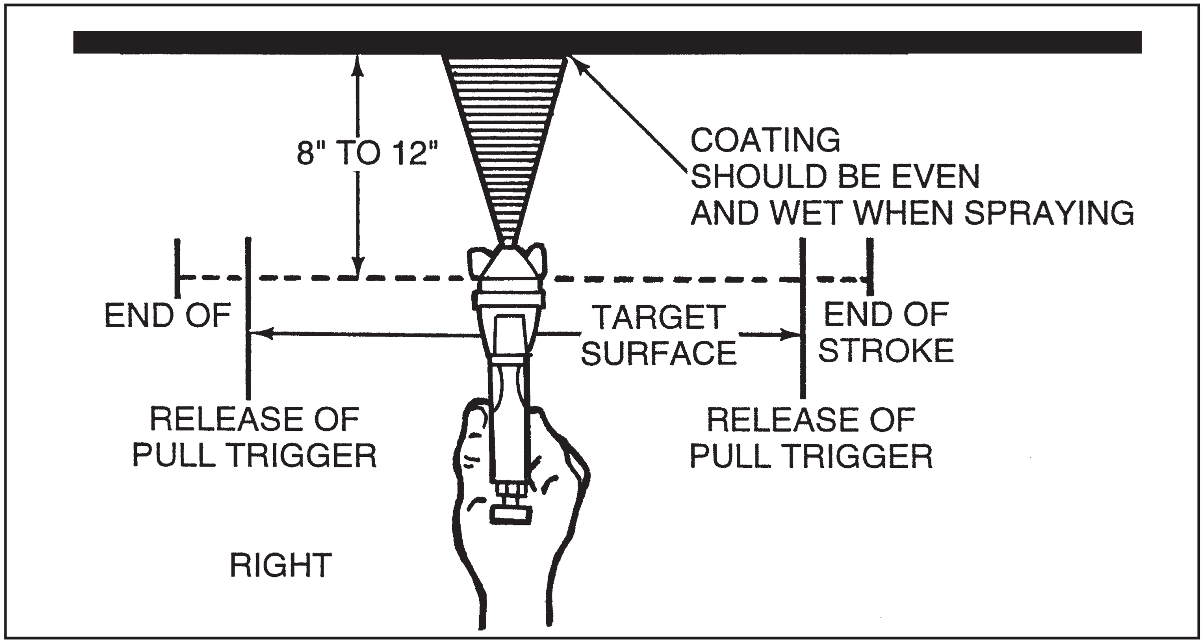

8" TO 12"
COATING
SHOULD BE EVEN
AND WET WHEN SPRAYING
END OF
TARGET
SURFACE
END OF
STROKE
RELEASE OF
PULL TRIGGER
RELEASE OF
PULL TRIGGER
RIGHT

Figure 15

Table 19 – Table Of Parameters/Trends In Movement

1. Gun distance*	Increase distance Decrease distance	— Lowers transfer efficiency; drier paint film. lighter color — Raises transfer efficiency; wetting paint film, darker color
2. Fluid deliveries*	Increase fluid Decrease fluid	— Raises transfer efficiency; wetter film, darker color — Lowers transfer efficiency; drier film, lighter color
3. Air pressure*	Raise air Lower air	— Lower transfer efficiency; drier film, lighter color — Higher transfer efficiency; wetter film, darker color
4. Coat split-up first coat — wetter First coat — drier and/or less film Second coat — wetter and/or more film Second coat — drier and/or less film		— More flow, darker color, excessive film could wet back second coat coat and mottle. — More orange peel, lighter color too dry, could cause lack of fusion between coats, resulting in blotchy color. — Darker color, excessive second coat could mottle. — Lighter color, insufficient film-build to cover first coat could result in blotchy color.

Manual Spray Guns And Applications (cont'd)

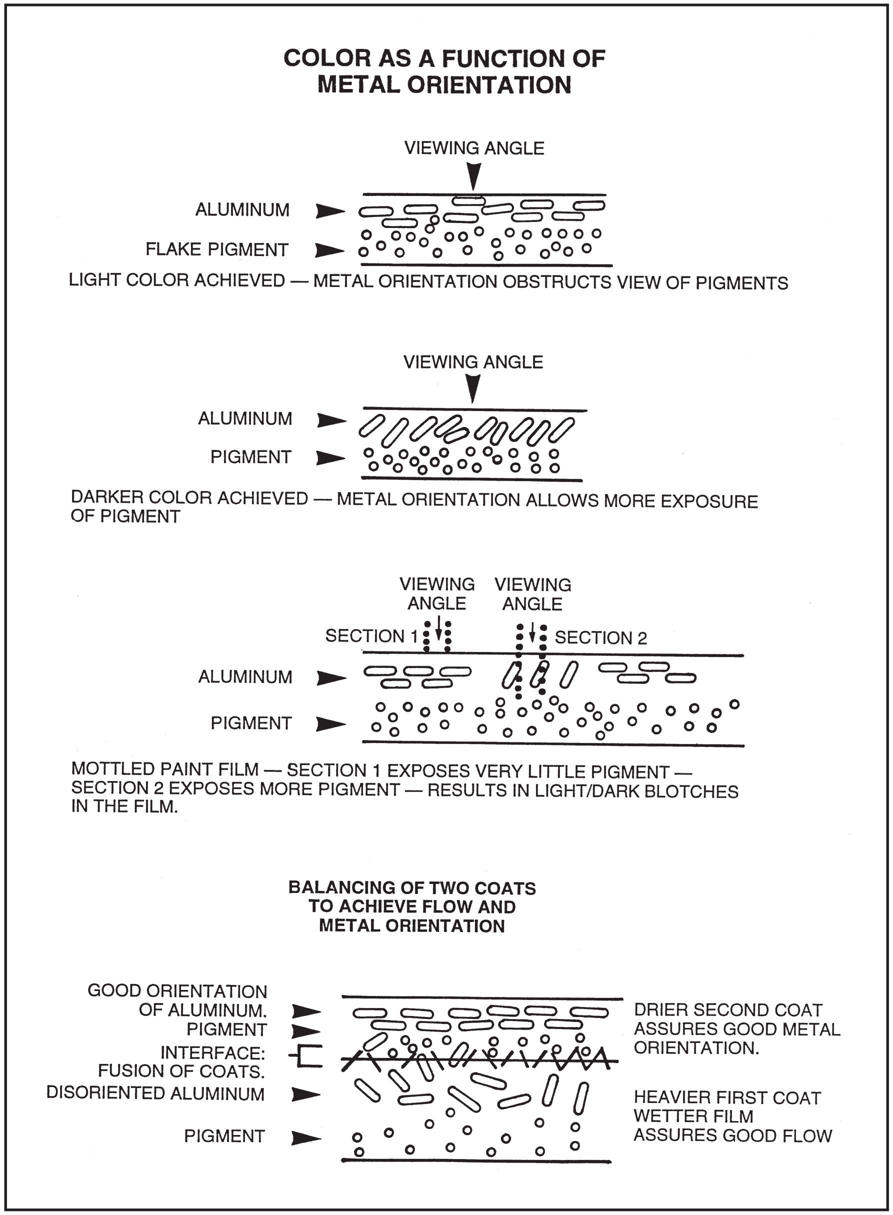

COLOR AS A FUNCTION OF METAL ORIENTATION
VIEWING ANGLE
ALUMINUM
FLAKE PIGMENT
LIGHT COLOR ACHIEVED — METAL ORIENTATION OBSTRUCTS VIEW OF PIGMENTS
VIEWING ANGLE
ALUMINUM
PIGMENT
DARKER COLOR ACHIEVED — METAL ORIENTATION ALLOWS MORE EXPOSURE OF PIGMENT
VIEWING ANGLE
VIEWING ANGLE
SECTION 1
SECTION 2
ALUMINUM
PIGMENT
MOTTLED PAINT FILM — SECTION 1 EXPOSES VERY LITTLE PIGMENT — SECTION 2 EXPOSES MORE PIGMENT — RESULTS IN LIGHT/DARK BLOTCHES IN THE FILM.
BALANCING OF TWO COATS TO ACHIEVE FLOW AND METAL ORIENTATION
GOOD ORIENTATION OF ALUMINUM.
PIGMENT
INTERFACE: FUSION OF COATS.
DISORIENTED ALUMINUM
PIGMENT
DRIER SECOND COAT ASSURES GOOD METAL ORIENTATION.
HEAVIER FIRST COAT WETTER FILM ASSURES GOOD FLOW

Figure 16

Solvent Rub Testing Of Coats

Use the solvent rub test to determine if the paint film is properly cured. This specification provides the proper procedures for conducting solvent rub testing on organic coatings. See Appendix I of this manual for correct solvent for use with a particular coating. Complete air dry systems may require 72 hours or more to achieve cure necessary to pass this test.

Solvent Wipe Procedure

Follow these steps when performing a solvent rub test:

- Select representative sample for evaluation.
- Soak a small cloth with the appropriate solvent. Squeeze out excess.
- Using forefinger and a 1- to 2-inch back-and-forth motion, apply 10 double rubs. (One complete back-and-forth motion equals one double rub.) Apply firm pressure (ideally, enough to produce a squeaking sound) while rubbing.
- Inspect the paint surface for any changes. It may also help to examine the cloth for paint residue. Use Table 20 (below) to assign a rating.

Table 20 – Solvent Rub Test Ratings

Rating	Paint Surface	Paint Residue on Cloth
0	No change	None
1	Slight – barely observable	Trace amount
3	Moderate – readily noticeable	Readily noticeable
5	Severe – very obvious	Saturated with color

Appendix I

Transit Coating (Optional)

This section briefly outlines key characteristics of transit coating materials required for all export vehicles. See GM specifications 9982223 and 9982224 for specific product details.

Apply acrylic water-based sprayable air-dry transit coating (9982223) by air-atomized spray.

- Typical V.O.C. is 00-1.0 lb. V.O.C./gallon
- Typical volume solid is 22%
- Application parameters are:
  - Spray to 0.2-0.4 mil. (0.3 target) to match approved appearance panel.
  - Spray all horizontal surfaces (shippable vehicles only).
  - Transit coating must air dry within one minute. Forced air or infrared (IR) may be used.

Transit coating must be removable by amine solution (9982224) produced by same supplier.

Properties

The specification in Appendix I outlines the key process controls for acrylic water-based sprayable air-dry transit

- dilution
- atomizing air
- fluid flow
- gun speed and distance
- ambient air temperature
- relative humidity

All parameters must be adjusted to allow for uncontrollable variances in temperature and humidity. A highly atomized application of transit coating is necessary to decrease air-dry time, but the coating must also completely “knit” together to form one uniform coating.

A properly applied transit coating is uniform in film-build and resembles a dull, hazy paint finish. When dry, the coating is hard and retains no tackiness. An inconsistent or low film-build reduces the level of protection against penetration of any foreign material. Heavy film-build does not usually significantly increase the protection level provided by normal film-builds. It does, however, increase the difficulty in removing the coating and may actually result in a hazed paint surface beneath the coating. Hazing can be attributed to transit coating residue that cannot be removed.

Remove transit coatings with amine solutions that are alkaline but nonhazardous and available for manual use.

Transit Coverings (Preferred)

The preferred method of shipping protection is to use applied transit film. The transit films are found under GM specification 9984168. Also full vehicle covers are acceptable.

Appendix I (cont'd)

! All materials and suppliers mentioned in this section are GM-approved but not required for use in conversions. These are general recommendations only.

! All systems should be tested and verified by the supplier over each particular substrate.

Table 20 – Solvent Rub Test Ratings

Application Parameters	Film-Build	Dry Time	Effectiveness	Removability	Transfer Efficiency
Gun Distance	A	A	C	C	A
Gun Speed	A	B	C	C	B
Line Speed	A	A	C	C	B
Atomizing Air	A	A	B	B	A
Fluid Flow	A	A	C	B	A
Film-Build	A	A	A	A	C
Ambient Air Temperature	C	B	C	C	B
Relative Humidity (RH)	C	A	C	C	C
Air Speed	C	B	C	C	A
Viscosity	C	A	C	C	B
Coating Temperature	C	B	C	C	C
Dilution	A	A	C	C	A

Note: See key and discussion for explanation.

A = Key Process Control – significant effect

B = Key Process Control – medium effect

C = Key Process Control – little or no effect

Appendix I (cont'd)

Fluid Delivery Rate

Fluid delivery rate or fluid flow is the rate at which transit coating is delivered to the gun. This measurement can be taken using a beaker and stopwatch. As the fluid delivery rate increases, the dry film-build increases. Also, as the line speed or gun speed decreases, the film-build increases as shown in Figures A-1 and A-2. Fluid flow is a determining factor in the amount of transit coating applied. This parameter is critical to film-build, which in turn is critical to dry time.

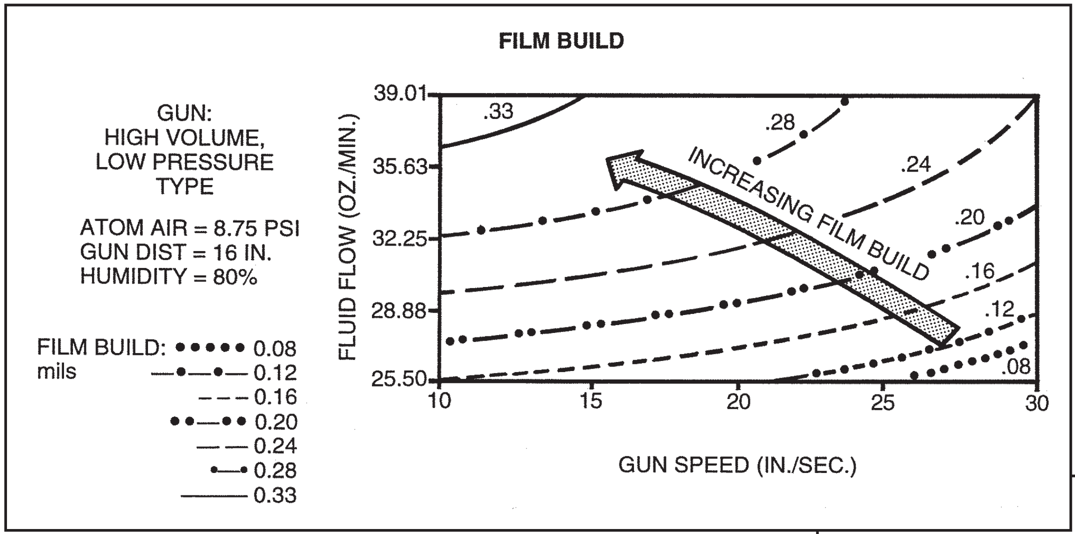


Figure A-1

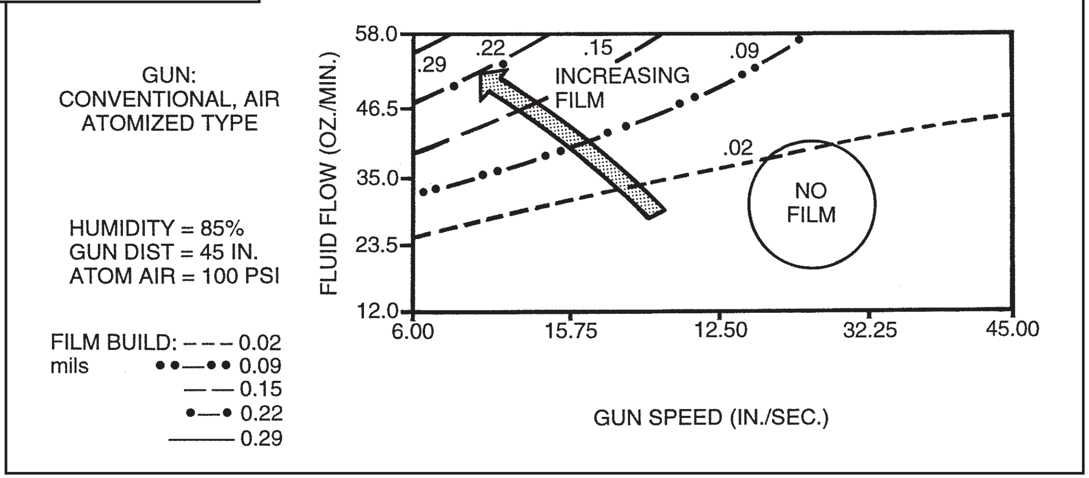


Figure A-2

Appendix I (cont'd)

Atomizing Air Pressure

Atomizing air is the air pressure used to shear or break up the transit coating into fine particles. Standard ranges for this value vary based on equipment, fluid flow, ambient humidity and temperature.

- The atomizing air will determine the amount and size of the transit coating's particles as they reach the surface. This will affect the film build and the drying time. Increasing the atomizing air pressure decreases the film-build.
- This effect is more dramatic with a conventional air-atomizing gun. These relationships are illustrated in Figures A-3 and A-4. The are less dramatic with the dry time decreases that occur with increasing air pressure using a conventional gun (though not illustrated here).

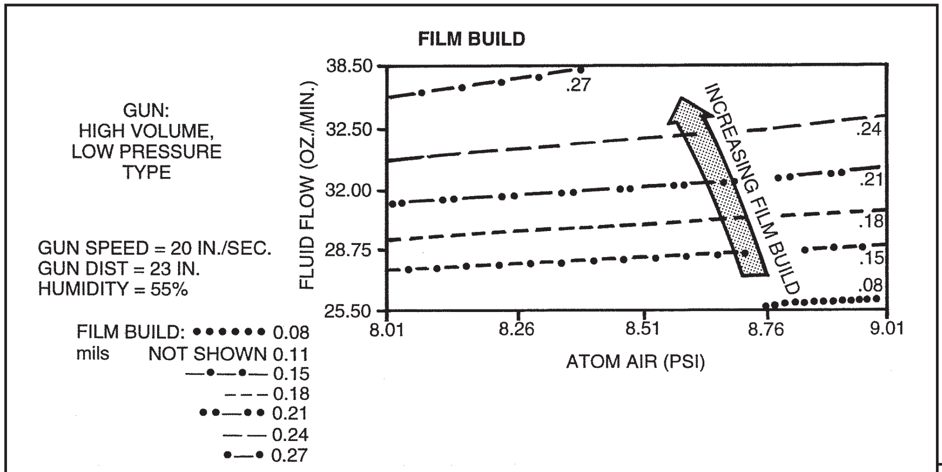


Figure A-3

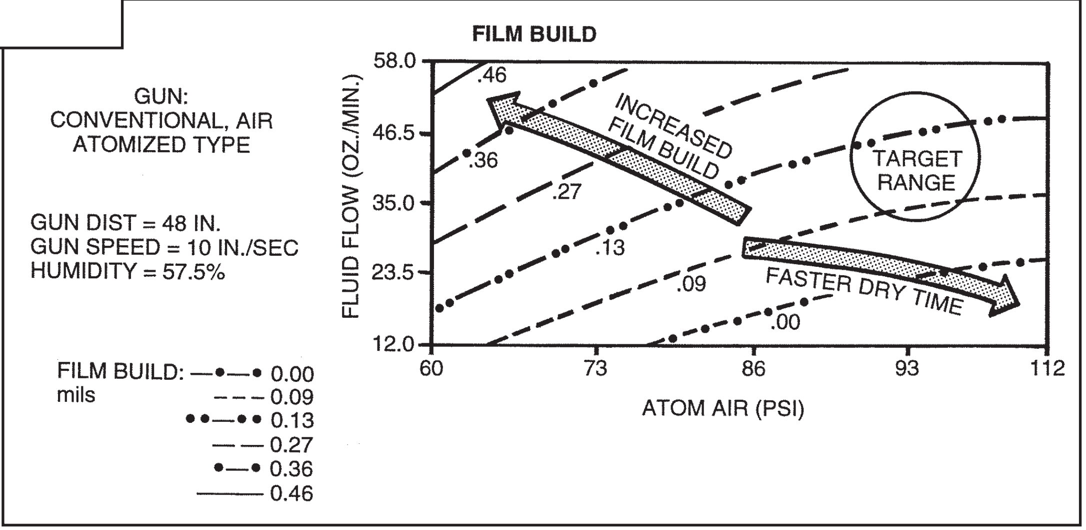


Figure A-4

Appendix I (cont'd)

The relationship between atomizing air and Transfer Efficiency (TE) is inversely proportional. That is, as atomizing air pressure increases, TE decreases.

Dilution

Dilution, which refers to the amount of water mixed with the virgin transit coating, influences the percentage of solenoids in the coating droplets as they are sprayed. The strength of dilution directly affects the film-build, which affects drying time, effectiveness, and removability.

- Lack of dilution reduces drying time, but also decreases efficiency.
- Lowering the dilution decreases drying time and increases film-build (for a constant flow rate).

As illustrated in Figure A-5, TE increases as dilution increases. For a constant film-build, a material diluted 1:1 would require an approximate fluid delivery which relates to half that fluid delivery rate for undiluted material.

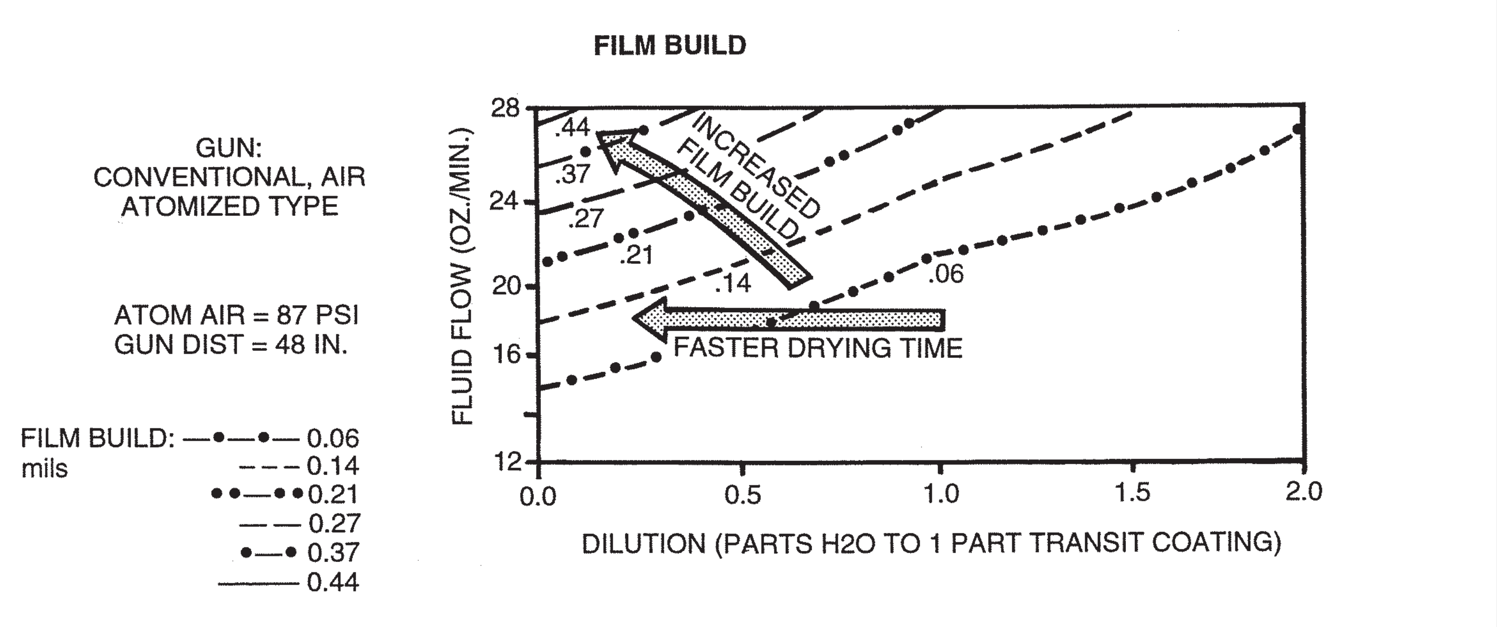


Figure A-5

Appendix I (cont'd)

Gun Distance

Standard measurement for all types of equipment is normally from the gun cap face to the target surface.

- The shorter the distance from the gun to the target, the greater the film build. (See Figure A-6.)
- Increasing gun distance reduces dry time. This is because water evaporates more quickly from airborne spray droplets than from the target surface (Figure A-7).
- Gun distance also affects the amount of transit coating deposited on the surface. This significantly affects film build, which influences dry time, effectiveness and removability.
- TE and gun distance are inversely proportional.

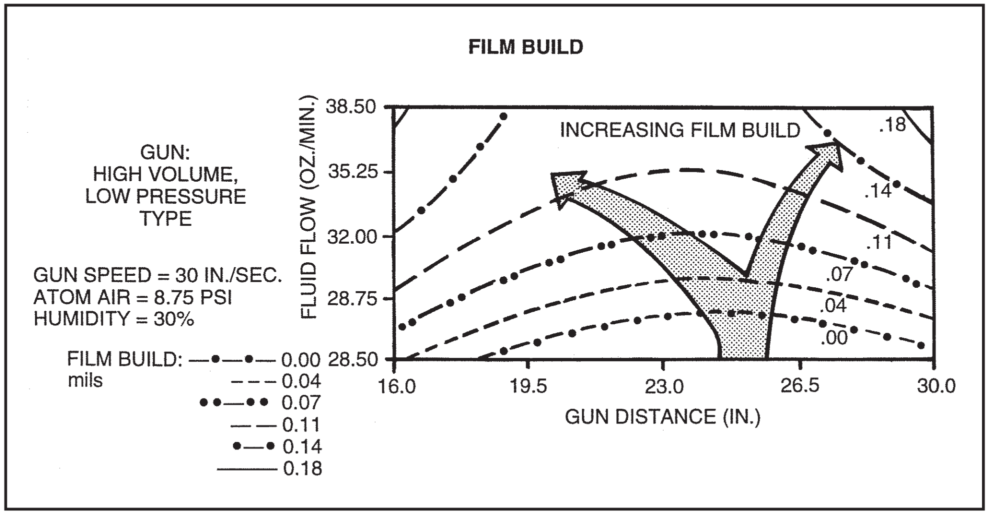


Figure A-6

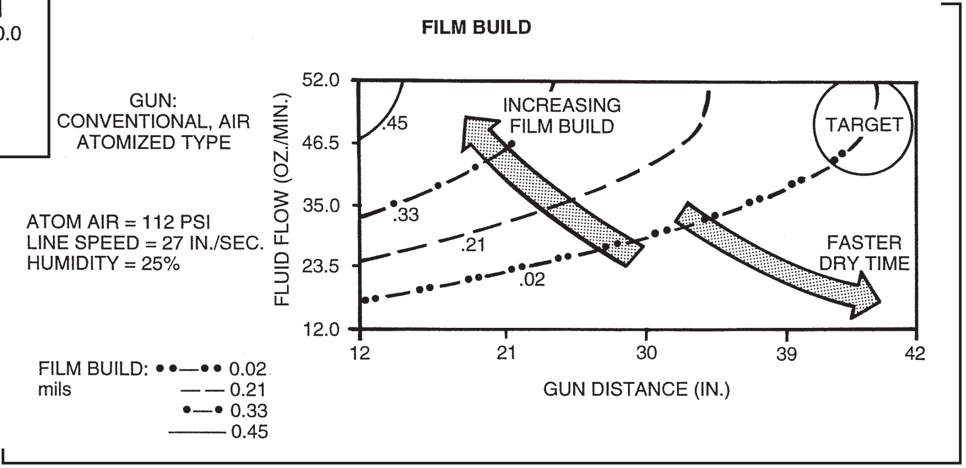


Figure A-7

Appendix I (cont'd)

Relative Gun Tip Speed (Conveyor Speed)

Gun speed is the velocity at which the spray gun travels in relationship with the target. Because it is fixed under normal operating conditions, it is less critical than other application parameters. Gun speed is usually determined by the number of jobs per hour, or line speed.

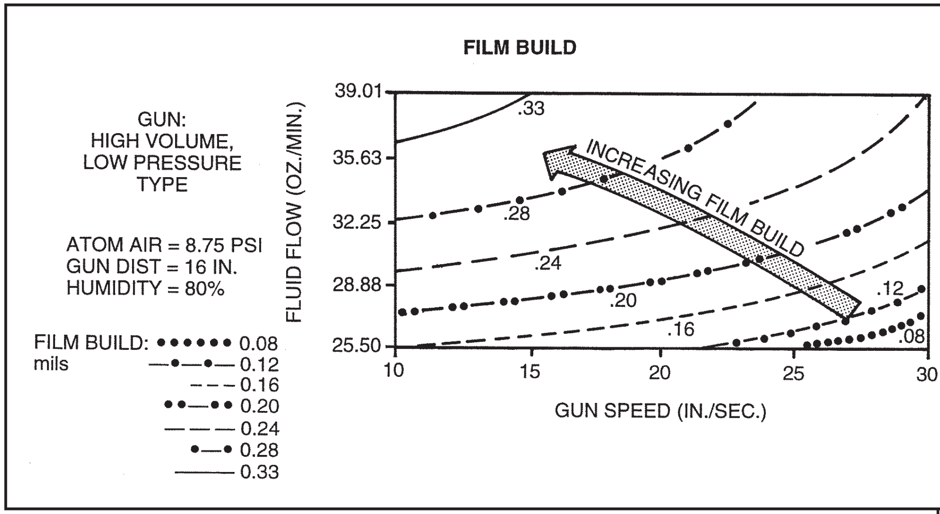


Figure A-8

- Slower gun/line speed (with constant flow rates) increases film-build.
- Dry time increases with slower gun/line speed.
  The general relationship is shown in Figures A-8 and A-9.

Decreased gun/line speed reduces dry time. This is because less fluid is required to achieve the filmbuild. The lower the flow rate, the longer the wet material remains in the region of atomization. The longer the material is in the region of atomization, the finer the particles. The larger the total surface area on the fluid being evaporated, the faster the mass transfer process.

! Equipment that is fixed should be checked to ensure that it does not vary with use. This parameter should be optimized prior to setting up the equipment.

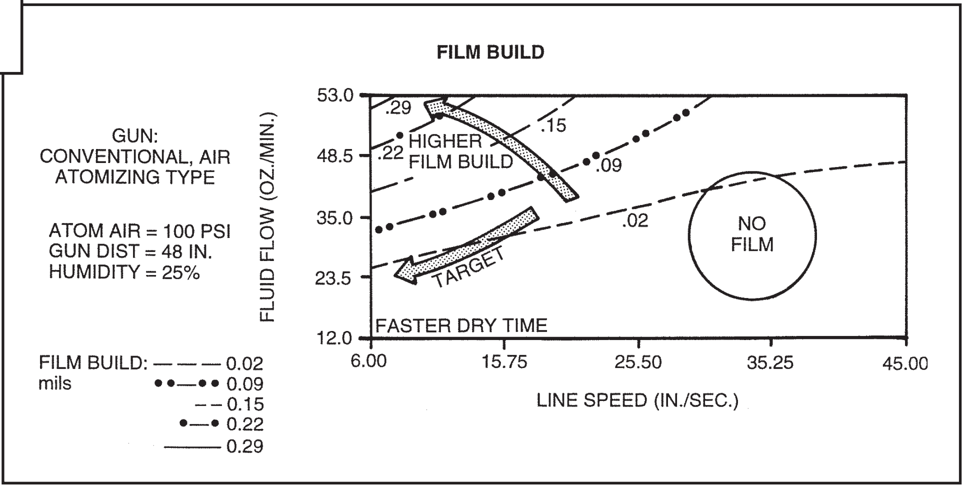


Figure A-9

Appendix I (cont'd)

Ambient Air Temperature

Ambient air temperature refers to the temperature inside the booth where the vehicle is sprayed. In a typical plant transit coating application system, temperature is rigidly controlled. Temperature can, however, be measured and other parameters can be adjusted to ensure consistency in the coating process.

- Temperature primarily affects the dry time because of its effect on relative humidity.
- Air temperature has no effect on wash-off time or film build. (See Figure A-10.)
- Increasing fluid flow rate increases the dry time. This is because it increases the amount of wet material reaching the target and thus the evaporation time of water contained in the wet material.

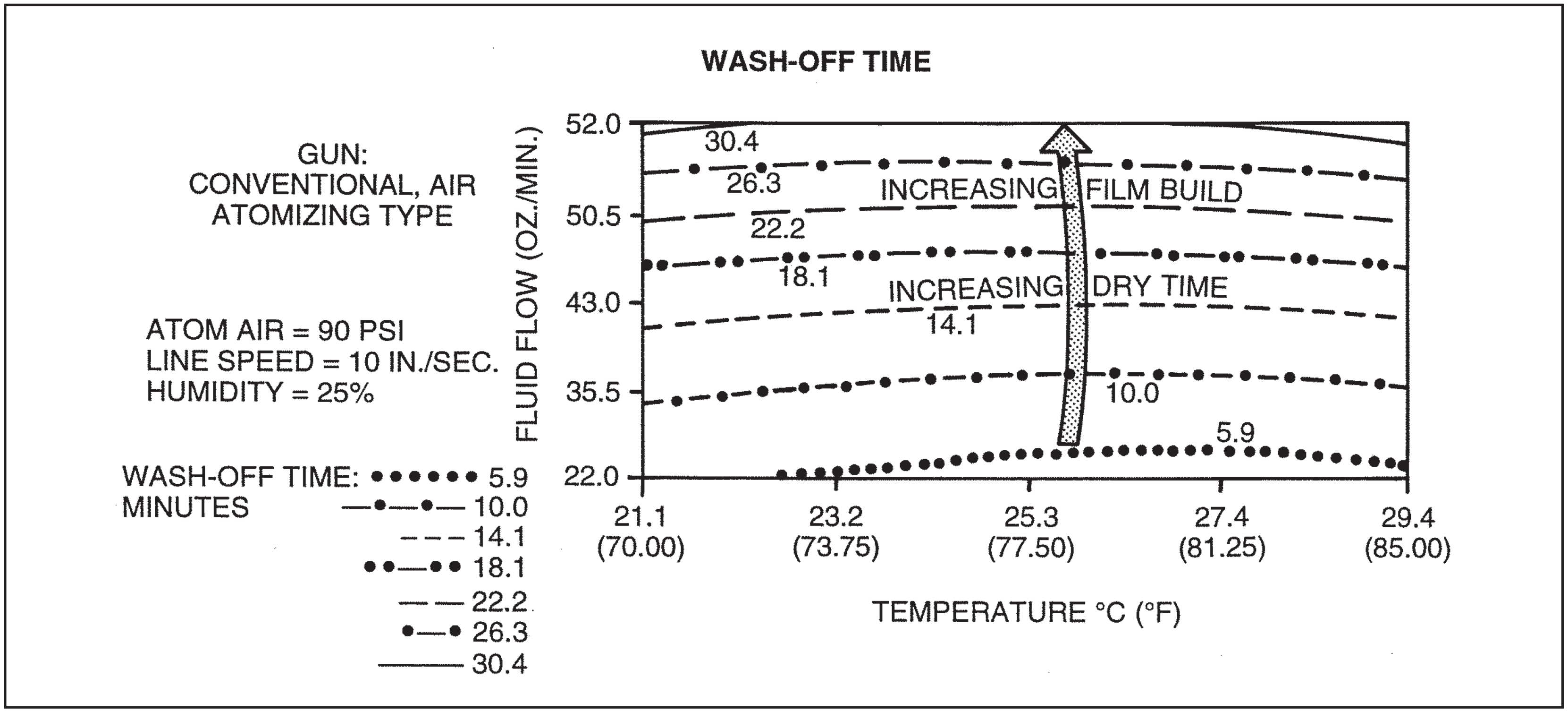


Figure A-10

Appendix I (cont'd)

Relative Humidity

Relative Humidity (RH) refers to the amount of water carried by the air inside the booth. It is expressed as a percentage of the capacity of the air to carry water at a specific temperature.

! RH should be checked often. Like temperature, RH will most likely not have controlling equipment. Other parameters, however, can be adjusted to ensure consistency in the coating process.

- RH drastically affects dry time, which increases as RH rises.

Wash time is the curing time required in a given ambient temperature which will prevent the transit coating from coming off in the rain. Figure A-11 shows the relationship between RH and wash time.

CAUTION A constant film-build should be maintained.

- Wash time is increased by both increased humidity and increased flow rate. This relationship is explained in the previous section.

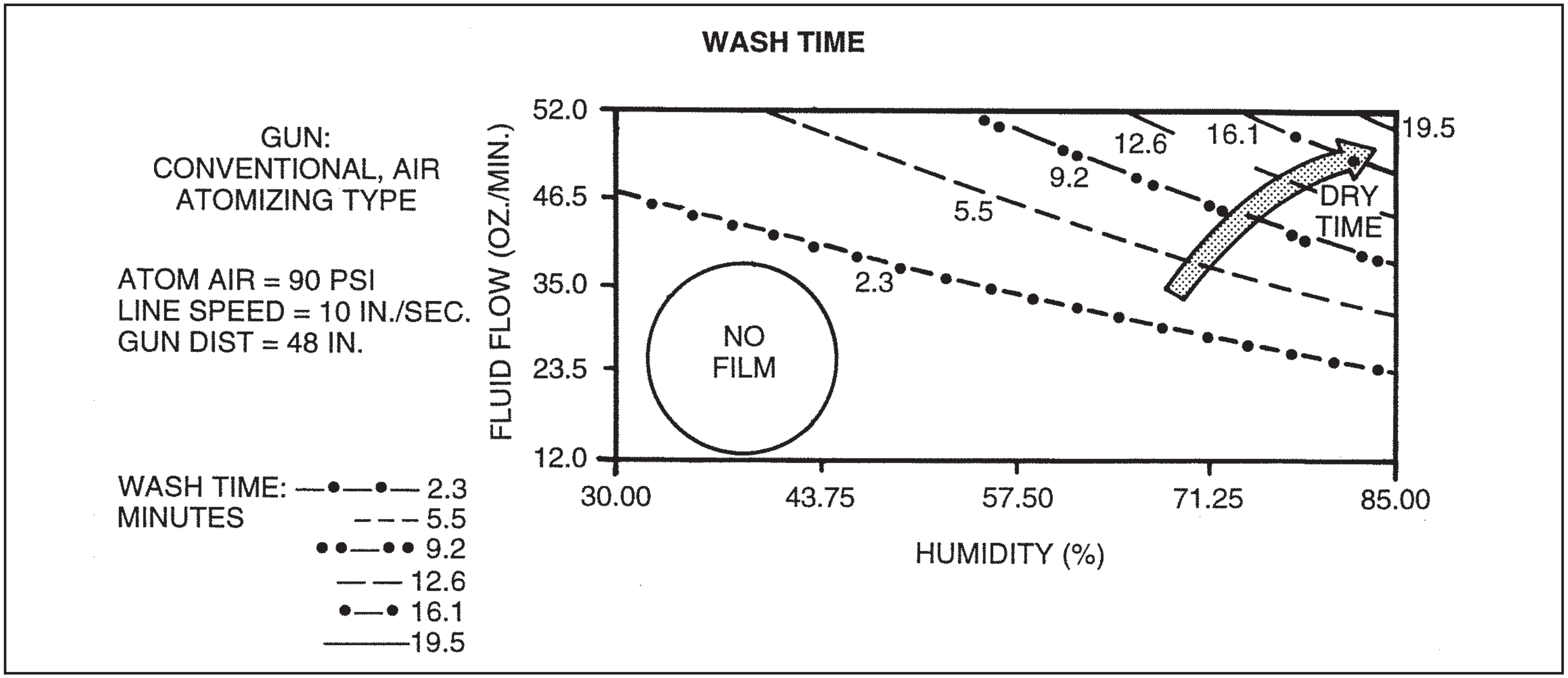


Figure A-11

Appendix I (cont'd)

Maintenance and Cleaning

Guns should be monitored and cleaned as required during production to prevent excessive overspray from generating a dirt defect in the painted surface. Specified solvent can be used with particular care given to the gun packing for possible deterioration. Gun packing should be reseated or replaced, and lubrication performed on a routine basis.

Lubrication Of Gun Parts

The fluid needle packing (a), air valve packing (b), trigger bearing screw (c), and the fluid needle spring (d) should be lubricated as required per manufacturer's recommendation. (See Figure A-12.)

CAUTION Do not use lubricants that contain silicone. Doing so will cause cratering on topcoats or primers.

Perform all spray-gun lubrication outside the paint shop.

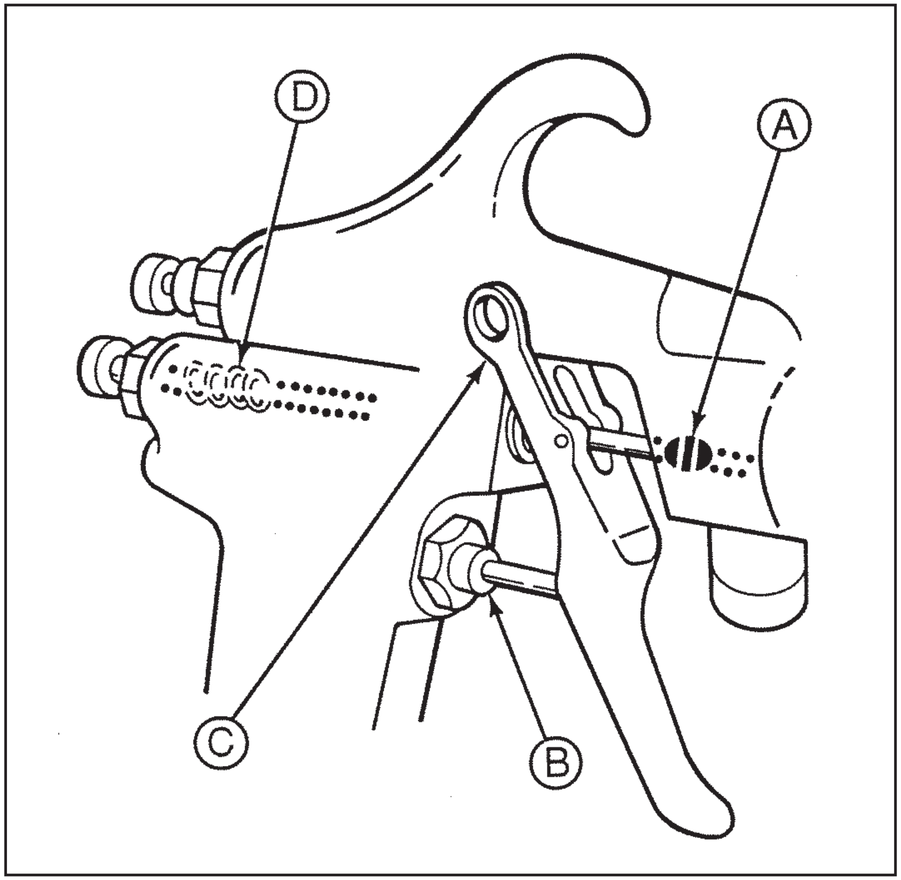


Figure A-12

Appendix I (cont'd)

General Spray Gun Assembly

Figure A-13 shows spray gun assembly components.

Air Adjustment Valve

This adjustment screw controls the amount of air through the air horn holes on the air cap. It allows regulation of the spray pattern or “spray fan.” For example, turning the screw counterclockwise increases the amount of air entering the air cap and results in an increased fan width.

Fluid Adjustment Valve

This adjustment screw controls the amount of fluid entering the fluid tip. For example, turning the screw counterclockwise increases the material entering the fluid tip.

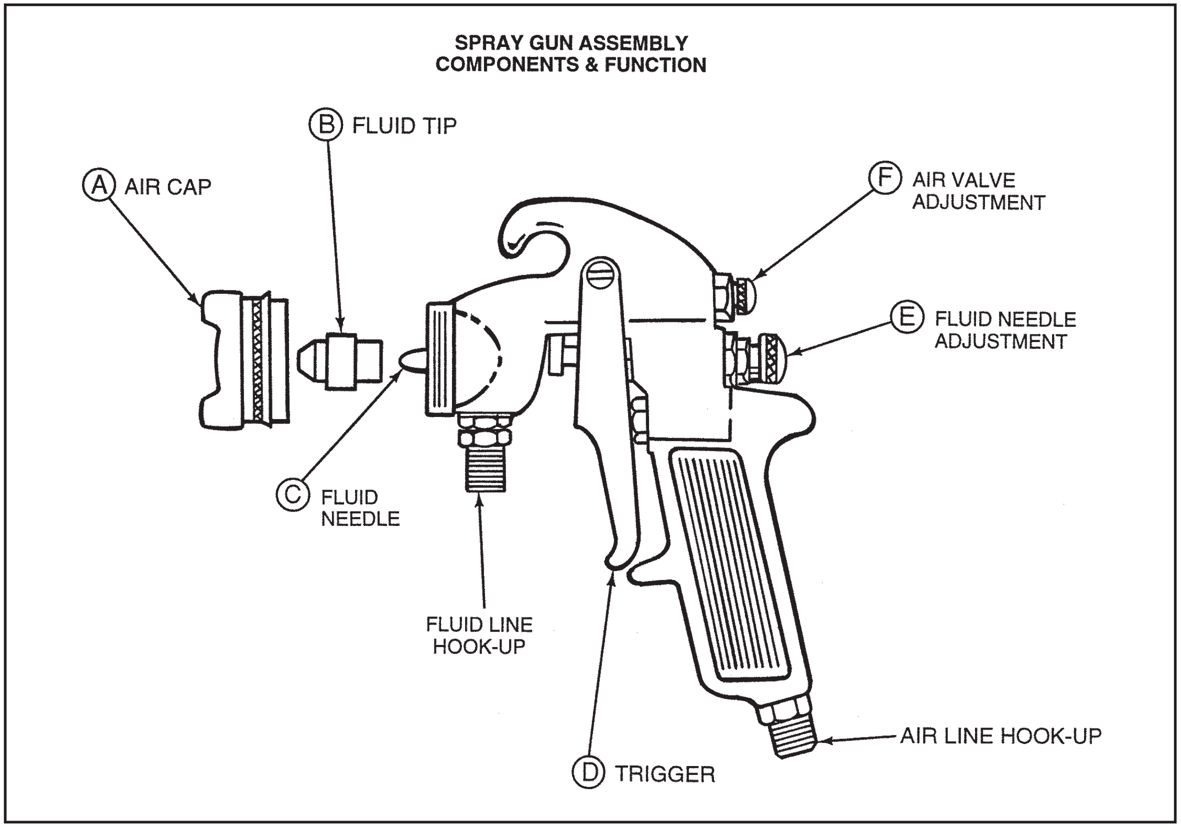

SPRAY GUN ASSEMBLY
COMPONENTS & FUNCTION
B FLUID TIP
A AIR CAP
F AIR VALVE ADJUSTMENT
E FLUID NEEDLE ADJUSTMENT
C FLUID NEEDLE
FLUID LINE HOOK-UP
AIR LINE HOOK-UP
D TRIGGER

Figure A-13

Appendix II

GM

2016

GM Globally Approved Refinish Materials

GMW-15406-2016

2016 GM Globally Approved Refinish Materials

Foreword

The products listed in this booklet have been approved by GM following a thorough, standardized test process to meet the GMW15406M Specification. This specification is for all countries where GM vehicles are manufactured, sold or repaired.

Only the products listed, and their support products (i.e., reducers) can be used for GM warranty work. This booklet supersedes previous publications.

Primers, surfacers, sealers, basecoats and clearcoats approved to meet this specification create a complete SYSTEM and are not interchangeable. Mixing products from different manufacturer-approved lines or the use of any generic substitutions are strictly forbidden. Unapproved substitution will result in voiding the manufacturers' warranty and a loss of GM-approved payments (charge backs) for warranty work. Although warranty franchise agreements for repair pertain to North American dealers and their sublets only, GM highly recommends global adoption of this specification. This booklet contains product information based on the latest data available at the time of publication approval. The right is reserved to make product or publication changes at any time, without notice.

This booklet, or any portions thereof, may not be reproduced without the written consent of General Motors, LLC.

Published by
North American Operations
General Motors, LLC,
Warren, Michigan 48090-9003

©2015 General Motors LLC
All rights reserved.

All brands and product names are registered trademarks of their respective owners.

Appendix II (cont'd)

General Information

General Information 3
- General Information 3

Manufacturers and Testing 4
- Approved Paint System Categories 4
- Paint Manufacturers 4
- Testing for the GMW15406 Specification 4

Globally Approved Refinish Materials 5
- AkzoNobel 5
- Cromax® 18
- Spies Hecker® 22
- Standox® 25
- BASF Glasurit 28
- BASF R-M 30
- Nexa Autocolor 32
- PPG - Deltron Systems 36
- PPG - Global Systems 41
- Martin-Senour 46
- Sherwin-Williams 49
- Valspar Automotive - DeBeer Refinish 52
- Valspar - Octoral 53

Contact Information

For further information on paint suppliers, go to the following web sites:

Paint Suppliers	Web Sites
AkzoNobel Coatings	www.akzonobelcarrefinishes.net
Axalta Coating Systems	www.axaltacs.com
Cromax (N. America)	www.cromax.us
Cromax (Europe)	www.cromax.com
Spies Hecker (N. America)	www.spieshecker.us
Spies Hecker (Europe)	www.spieshecker.com
Standox (N. America)	www.standox.us
Standox (Europe)	www.standox.com
BASF	www.basfrefinish.com
PPG	www.nexaautocolor.com
Nexa Autocolor	www.nexaautocolor.com
PPG	www.ppgrefinish.com
Sherwin-Williams	
Martin-Senour	www.martinsenour-autopaint.com
Sherwin-Williams	www.sherwin-automotive.com
Sherwin-Williams (Europe)	www.sherwineu.com
Sherwin-Williams (Brazil)	www.sherwin-auto.com
Sherwin-Williams (China)	www.sherwin-automotive.com.cn
Valspar	
DeBeer	www.de-beer.com
Octoral	www.octoral.com

Introduction

General Motors continuously pursues quality improvement. Therefore GM has established automotive refinishing standards for itself as well as its Marketing Division Dealers and Retailers. GM was the first domestic car company to set a specification for aftermarket paint finishes.

GM has established standards for paint refinishing. Each Division requires the Dealer to use only materials and methods that meet GM Standard GMW15406 when repairing, replacing, or refinishing vehicles. Where it is determined that the Dealer is using paint systems or materials which do not meet GMW15406 standards, appropriate counsel and/or corrective action may be taken.

The Bottom Line

Dealer(s) or Retailer(s) in North America, must ensure that all finish repairs, including sublets, meet GM Specification GMW15406. Use of materials (and associated methods) that do not meet this GM standard may result in a review of claim(s) leading to chargeback(s).

As warranty periods increase, customer expectations continue to rise. Many Dealers/Retailers understand customer expectations. As a result, they have chosen a single, complete system approach and only use the systems that meet the highest standards of quality and durability.

All the paint manufacturers that meet the GMW15406 Specification have spent thousands of man hours in research and development to ensure the approved system gives the appearance, performance, and durability comparable to the OEM finish. The products in the systems listed in this book are the very best products to use. They are guaranteed to produce the consistent, quality results that GM customers expect. This makes it easier for you, as the Dealer/Retailer, to confidently choose a system that will maximize your customers' satisfaction.

Each year, all new paint systems will be tested and evaluated. New or improved products will also be tested. The paint systems that pass this annual testing process will be published in this booklet, updated annually.

The National Rule was implemented in January 1999. You are required to use only VOC systems listed in this book for business in the United States. Some non-VOC systems that meet GMW15406 Specifications are still approved for Canada. For other countries, check with our paint supplier to see if a listed non-VOC system is one of those.

Appendix II (cont'd)

Paint Manufacturers

The Manufacturers and their Paint Refinish Systems that have passed the GMW15406 Specification are:

- AkzoNobel Coatings, Inc.
- Axalta Coating Systems
- BASF
- DeBeer
- Martin-Senour
- Nexa Autocolor
- Octoral
- PPG
- Sherwin-Williams
- Valspar

Testing for the GMW15406 Specification

To meet this specification, each manufacturer has conducted the following tests for their paint refinish systems:

- Tukon Hardness—point of hardness of paint film after cure
- Humidity Adhesion—durability of paint films exposed to rain and damp weather conditions
- Chip Resistance—resistance of paint films to stone chipping and or small mars caused by road dirt/gravel
- Cycle Test—durability of paint films going from cold-to-hot-to-cold or hot-to-cold-to-hot conditions
- Gas Resistance—resistance of paint to staining or softening when exposed to gasoline
- Chemical Resistance—resistance to environmental chemicals/ products
- Weather Resistance—overall long-term durability of the paint system as related to cracking, crazing, fading, hazing, fogging or any other customer dissatisfaction issues

Approved Paint System Categories

Because of environmental concerns, rules involving Refinishing products in Europe and North America have been established. The intent of these rules is to limit the amount of volatile organic compounds (VOCs) emitted into the air during the refinish process. The 2015 GMW15406 book recognizes four categories of regulations.

US National Rule: In 1998, the United States Environmental Protection Agency established the National Rule for Automotive Refinish Coatings. The National Rule regulates VOC emissions in the United States unless it is superseded by a local air district or state that has more stringent rules for emissions standards, such as The Bay Area Air Quality Management District Rule 8-45 that includes San Francisco, California; The South Coast Air Quality Management District Rule 1151, that includes Los Angeles, California; The Delaware Division of Air Quality rule 1124 section 11; and Maryland COMAR 26.11.19.23.

US SCAQMD Rule 1151: The South Coast Air Quality Management District (SCAQMD) is the air pollution control agency for all of Orange County and the urban portions of Los Angeles, Riverside and San Bernardino counties. In 1988, this District was the first jurisdiction in the world to develop VOC concentration limits for some Automotive Refinishing products. The latest version of Rule 1151 amended September 5, 2014, based on the CARB SCM (California Air Resources Board Suggested Control Measure) model rule, mandates the least VOC emissions in the world. It is the leader that all jurisdictions look to when setting rules for their respective districts. A number of air districts in California, including Bay Area and San Diego, have rules based on the CARB SCM with similar VOC limits as Rule 1151. Other States that follow 1151 include; Maryland rule COMAR 26.11.19.23, Delaware rule 1124 section 11, and the Utah rule 307-354. The Canada Gazette Part II SOR/2009-197 rules are also based on the CARB SCM with similar VOC limits as Rule 1151.

Europe: The first European Union law to affect the Vehicle Refinishing sector was published in 1999. In 2004, the European Parliament adopted a new and common Directive limiting the emissions of Volatile Organic Compounds. This new Directive went into effect in 2007. This is published in the Official Journal of the European Communities, Council Directive 2004/42/CE.

Non-Regulated: Many countries in the world have yet to adopt regulations limiting VOC emissions. Consequently, there are no restrictions on the type of Refinishing products that can be manufactured, imported, sold and used in these areas.

These four categories represent the most prominent jurisdictions and rules – including non-rules – in the world. However, there are many more governmental districts with their own air quality regulations. California alone has over 30 local air districts. You should always check with your paint supplier to see if the system you are using meets the VOC requirements for your area.

There may be more than one paint system in a manufacturer's line that has met the GMW15406 Specification. Each system listed is complete, as tested, and no substitution, even of a similar product in another system, is acceptable. The manufacturers and their GM approved systems are laid out on the following pages for your ease of reference.

Appendix III

THE ONLY GAUGE EVER CHOSEN BY THE "BIG 3"

The new ETG Electronic Thickness Gauge
Now you can measure paint to 1/10 mil with the ETG multi-featured mil gauge — at a breakthrough price!

ETG®

THE NEW INDUSTRY STANDARD

ETG, is the first electronic paint gauge to measure up to the tough standards of the Chrysler and Ford dealer equipment programs. ETG was also chosen by General Motors Dealer Equipment, and is the gauge chosen for use in their new finessing training video. In short, ETG is the only gauge chosen by all of the "Big Three."

If you want your technicians to use the same paint gauge as the OEM's, you'll need the new ETG gauge. It is far ahead in both performance and price.

EASY TO USE

- Just touch "ON" and begin measuring
- ETG shuts off automatically &
- Does NOT need constant recalibration:
  Full range accuracy
  Stable & repeatable

FEATURES

- Memory to save readings
- Probe on cable for stable readings
- Automotive steel calibration plate and precision thickness foils
- Instruction summary on rear label
- USA factory service and support
- Mil/Micron switchable

BENEFITS WHICH KEEP YOUR BUSINESS IN THE BLACK

Solve common paint problems:

- See how much clearcoat is left.
- Find how deep acid rain damage is.
- Know when it's safe to buff the paint.
- Improve refinish consistency and quality.

Take advantage of a powerful business tool:

- Impress new customers and win their business.
- Cut expensive paint material waste and costs.
- Increase body shop sales by showing customers where more work, such as paint stripping or reclearcoating, is needed.
- Resolve customer disputes by proving previous paint damage.

Further information can be found at: http://www.gardco.com/pages/filmthickness/df/etg_gauge.cfm